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Water Quality Conditions at Tributary Projects in the Omaha District

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2006 Annual Report

Water Quality Conditions at Tributary Projects in the Omaha District

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U.S. Army Corps of Engineers

December 2007

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1 INTRODUCTION

1.1 OMAHA DISTRICT WATER QUALITY MANAGEMENT PROGRAM

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995). The following four goals have been established for the District's WQMP (USACE, 2007a):

1) Ensure that surface water quality, as affected by District projects and their regulation, is suitable for project purposes, existing water uses, and public health and safety, and is in compliance with applicable Federal, Tribal, and State water quality standards.
2) Establish and maintain a surface water quality monitoring and data evaluation program that facilitates the achievement of water quality management objectives, allows for the characterization of water quality conditions, and defines the influence of District projects on surface water quality.
3) Establish and maintain strong working partnerships and collaboration with appropriate entities within and outside the Corps regarding surface water quality management at District projects.
4) Document the water quality management activities of the District's Water Quality Management Program and Project surface water quality conditions to record trends, identify problems and accomplishments, and provide guidance to program and project managers.

Water quality data collection and assessment are of paramount importance to the implementation of the District's WQMP.

The periodic report of water quality conditions is prepared to document and assess water quality conditions occurring at Corps civil works projects in the District. The report describes existing water quality conditions and identifies any evident surface water quality management issues. The periodic reporting of project water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of Corps projects.

1.2 CORPS CIVIL WORKS PROJECTS WITHIN THE OMAHA DISTRICT

The location of Corps tributary civil works project areas within the District, and background information on the projects, are provided in Figure 1.1 and Table 1.1. These are the tributary civil works projects under the purview of the District's WQMP.

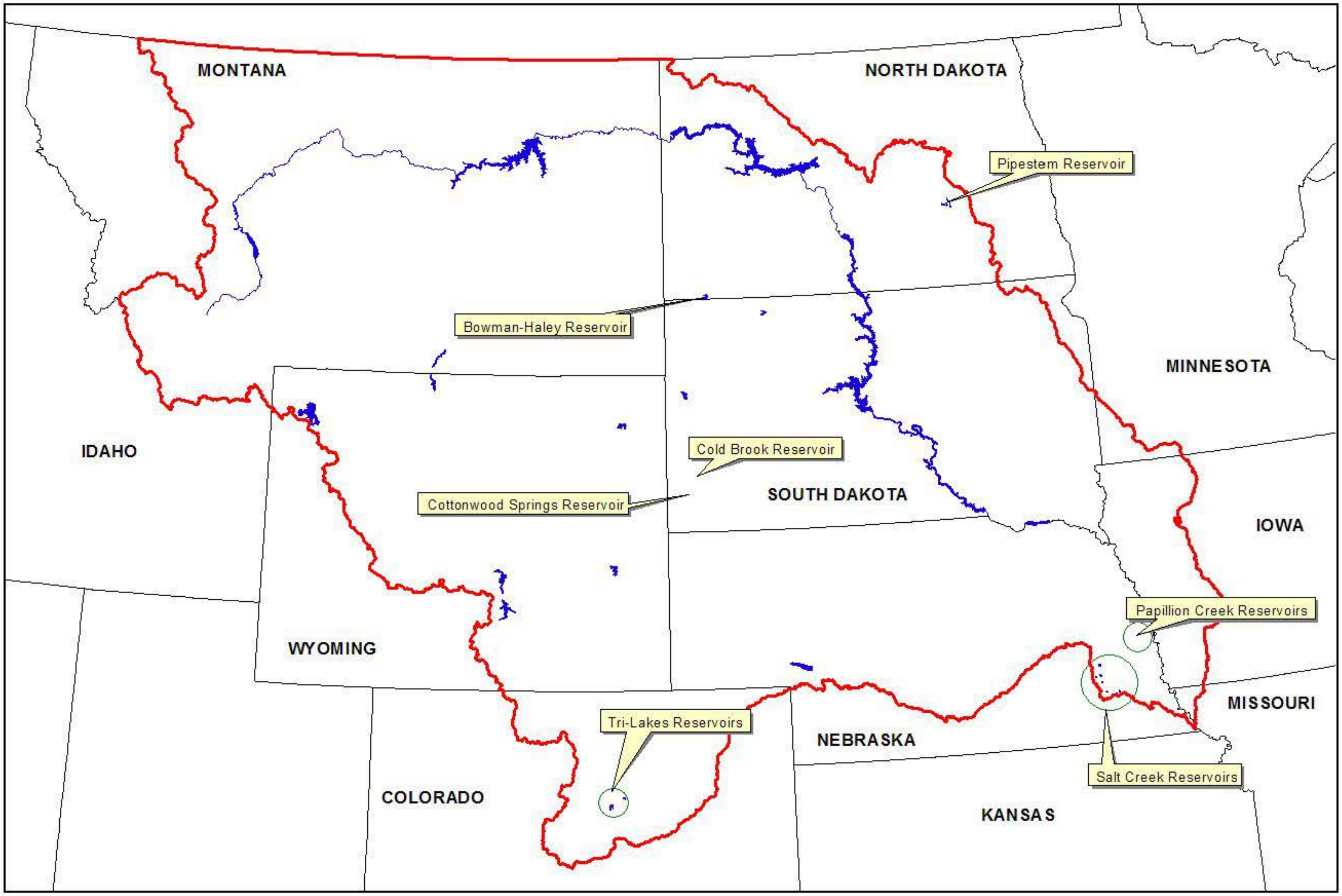

Figure 1.1. Tributary civil works projects in the Omaha District. (Refer to Table 1.1 for project information.)

Table 1.1. Background information for Tributary Corps water resource project areas located in the Omaha District.

Project Area	Location	Dam Closure	Lake Size (1)	Authorized Proposes(2)	Water Quality Designated Beneficial Uses(3)
Tri-Lakes Reservoirs (Colorado):					
Bear Creek	Denver, CO	1977	107 A (mp)	FC, Rec, FW	Rec, CAL, DWS, AWS
Chatfield	Denver, CO	1973	1,423 A (mp)	FC, Rec, FW, WS	Rec, CAL, DWS, AWS
Cherry Creek	Denver, CO	1948	844 A (mp)	FC, Rec, FW	Rec, WAL, DWS, AWS
Salt Creek Reservoirs (Nebraska):					
Bluestem (Dam #4)	Lincoln, NE	1962	309 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Branched Oak (Dam #18)	Lincoln, NE	1967	1,847 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Conestoga (Dam #12)	Lincoln, NE	1963	217 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Holmes (Dam #17)	Lincoln, NE	1962	123 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Olive Creek (Dam #2)	Lincoln, NE	1963	162 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Pawnee (Dam #14)	Lincoln, NE	1964	739 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Stagecoach (Dam #9)	Lincoln, NE	1963	195 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Twin Lakes (East and West) (Dam #13)	Lincoln, NE	1965	236 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Wagon Train (Dam #8)	Lincoln, NE	1962	277 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Yankee Hill (Dam #10)	Lincoln, NE	1965	211 A (mp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Papillion Creek Reservoirs (Nebraska):					
Ed Zorinsky (Dam #18)	Omaha, NE	1984	259 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Glenn Cunningham (Dam #11)	Omaha, NE	1974	377 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Standing Bear (Dam #16)	Omaha, NE	1972	125 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Wehrspann (Dam #20)	Omaha, NE	1982	239 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
North Dakota Reservoirs:					
Bowman-Haley	Bowman, ND	1966	1,732 A (mp)	FC, Rec, FW, WQ, WS	Rec, WAL, FW, AWS
Pipestem	Jamestown, ND	1973	840 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
South Dakota Reservoirs:					
Cold Brook	Hot Springs, SD	1952	36 A (mp)	FC, Rec, FW, WQ	Rec, FW, CAL, AWS, DWS
Cottonwood Springs	Hot Springs, SD	1969	41 A (mp)	FC, Rec, FW, WQ	Rec, FW, WAL, AWS, DWS

(1) A = acres, M = miles, mp = top of multipurpose pool.
(2) Purposes authorized under Federal laws for the operation of the Corps projects.
FC = Flood Control, Rec = Recreation, FW = Fish & Wildlife, WS = Water Supply, WQ = Water Quality.
(3) Water quality dependent beneficial uses designated to the water body in State water quality standards pursuant to the Federal Clean Water Act. Rec = Recreation, FW = Fish and Wildlife, WAL, Warmwater Aquatic Life, CAL = Coldwater Aquatic Life, DWS = Domestic Water Supply, AWS = Agricultural Water Supply, Aes = Aesthetics.

1.3 WATER QUALITY MONITORING GOALS AND OBJECTIVES

The District has established purposes and monitoring objectives for surface water quality monitoring under its WQMP. These monitoring purposes and objectives were established to meet the water quality information needs of the WQMP and the water quality management objectives, data collection rules and objectives, data application guidance, and reporting requirements identified in ER 1110-2-8154. Pertinent monitoring goals and objectives that have been established are:

Purpose 1: Determine surface water quality conditions at District projects.

Monitoring Objectives:

- For new District water resource projects, establish baseline surface water quality conditions as soon as possible and appropriate.
- Characterize the spatial and temporal distribution of surface water quality conditions at District projects.
- Identify pollutants and their sources that are affecting surface water quality and the aquatic environment at District projects.
- Evaluate water/sediment interactions and their effects on overall surface water quality at District projects.
- Identify the presence and concentrations of contaminants in indicator and human-consumed fish species at District projects.

- Investigate, as necessary, unique events (e.g., fish kills, hazardous waste spills, operational emergencies, health emergencies, public complaints, etc.) at District projects that may have degraded surface water quality or indicate the aquatic environment has been impacted.

Purpose 2: Quantify surface water concerns that exist and are due to the operation and reservoir regulation of District projects.

Monitoring Objectives:

- Determine if surface water quality conditions at District projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meets applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District projects.

Purpose 3: Provide data to support project operations and reservoir regulation for effective management and enhancement of surface water quality and the aquatic environment.

Monitoring Objectives:

- Provide surface water quality data required for real-time regulation of District projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District projects to enhance surface water quality and the aquatic environment.

Purpose 4: Evaluate the effectiveness of structural or regulation measures implemented at District projects to enhance surface water quality and the aquatic environment.

Monitoring Objectives:

- Evaluate the effectiveness of implemented measures at District projects to improve surface water quality and the aquatic environment.

1.4 DATA COLLECTION APPROACHES

Several data collection approaches have been identified by the District for collecting surface water quality data. Pertinent water quality monitoring approaches are:

- Long-term, fixed-station ambient monitoring;
- Intensive surveys;
- Special studies; and
- Investigative monitoring.

Long-term, fixed-station ambient monitoring is intended to provide information that will allow the District to determine the status and trends of surface water quality at District projects. This type of sampling consists of systematically collecting samples at the same location over a long period of time (e.g., collecting monthly water samples at the same site for several years).

Intensive surveys are intended to provide more detailed information regarding surface water quality conditions at District projects. They typically will include more sites sampled over a shorter timeframe than long-term fixed-station monitoring. Intensive surveys will provide the detailed water quality information needed to thoroughly understand surface water quality conditions at a project.

Special studies are conducted to address specific information needs. Special water quality studies may be undertaken to collect the information needed to “scope-out” a specific water quality problem, apply water quality models, design and engineer modifications at projects, or evaluate the effectiveness of implemented water quality management measures.

Investigative monitoring is typically initiated in response to an immediate need for surface water quality information at a District project. This may be in response to an operational situation, the

occurrence of a significant pollution event, public complaint, or a report of a fish kill. Any District response to a pollution event or fish kill would need to be coordinated with the appropriate Tribal, State, and Local agencies. The type of sampling that is done for investigative purposes is highly specific to the situation under investigation.

1.5 GENERAL WATER QUALITY CONCERNS IN THE OMAHA DISTRICT

1.5.1 RESERVOIR EUTROPHICATION AND HYPOLIMNETIC DISSOLVED OXYGEN DEPLETION

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The tendency toward the eutrophic or nutrient-rich status is common to all impounded waters. The eutrophication, or enrichment process, can be accelerated by nutrient additions to the reservoir resulting from cultural activities.

As deeper, temperate lakes warm in the spring and summer they typically become thermally stratified, due to the density differences of the water, into three vertical zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion. The epilimnion is the upper zone of less dense, warmer water in the lake that remains relatively mixed due to wind action and convection. The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent.

A significant water quality concern that can occur in reservoirs that thermally stratify in the summer is the depletion of dissolved oxygen levels in the hypolimnion. The depletion of dissolved oxygen is attributed to the differing density of water with temperature, the utilization of dissolved oxygen in the decomposition of organic matter, and the oxidation of reduced inorganic substances. When density differences become significant, the deeper colder water is isolated from the surface and re-oxygenation from the atmosphere. In eutrophic lakes, the decomposition of the abundant organic matter can significantly reduce dissolved oxygen in the quiescent hypolimnetic zone. Anoxic conditions in the hypolimnion can result in the release of sediment-bound substances (e.g., phosphorus, metals, sulfides, etc.) as the reduced conditions intensify and result in the production of toxic and caustic substances (e.g., hydrogen sulfide, etc.). Most fish and other intolerant aquatic life cannot inhabit water with less than 4 to 5 mg/l dissolved oxygen for extended periods. These conditions can impact aquatic life in the reservoir and also in waters downstream of the reservoir if its releases are from a bottom outlet.

1.5.2 SEDIMENTATION

Sedimentation is a process that reduces the usefulness of reservoirs. In the design and construction of reservoirs, the Corps will commonly allow for additional volume to accommodate sedimentation. The incoming sediment can seriously affect the reservoir ecology, fisheries, and benthic aquatic life. The reservoir can suffer ecological damage before a volume function such as flood control is impacted. The influx of sediment eliminates fish habitat, adds nutrients, destroys aesthetics, and decreases biodiversity. Working closely with the project sponsors in an effort to manage sediment input could ultimately prolong reservoir life. Wetlands or sediment traps could be constructed at the headwaters of a reservoir, either upstream of the reservoir or by taking a portion of the reservoir’s upper end, to trap sediment.

1.5.3 SHORELINE EROSION

Shoreline erosion is a major problem occurring on nearly all reservoirs located in areas of erodible soils such as the Midwest. Over 6,000 miles of reservoir shoreline exist at District projects, and it is estimated that over 70 percent of this shoreline is eroding. Some locations have been protected, such as recreational and archaeological sites, but most of the shoreline continues to erode. Continued loss of the shoreline habitat (littoral zone) results in the loss of fishery habitat as well as loss of habitat for other biota such as aquatic vegetation and benthic invertebrates.

1.5.4 BIOACCUMULATION OF CONTAMINANTS IN AQUATIC ORGANISMS

Bioaccumulation is the accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water or sediment. Bioavailable, for chemicals, is the state of being potentially available for biological uptake by an aquatic organism when that organism is processing or encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from the water as it passes through the respiratory cavity or the chemicals that are absorbed by internal membranes as the organism moves through or ingests sediment). In the aquatic environment, a chemical can exist in three different basic forms that affect availability to organisms: 1) dissolved, 2) sorbed to biotic or abiotic components and suspended in the water column or deposited on the bottom, and 3) incorporated (accumulated) into organisms. Bioconcentration is a process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill or epithelial tissue) and elimination. Biomagnification is the result of the process of bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of a chemical from food to consumer so that residual concentrations increase systematically from one trophic level to the next.

Bioaccumulation of contaminants can have a direct effect on aquatic organisms. These effects can be chronic (reduced growth, fecundity, etc.) and acute (lethality). The bioaccumulation of contaminants can also be a concern to human health when the contaminated tissue of aquatic organisms is consumed by humans.

1.5.5 OCCURRENCE OF PESTICIDES

Pesticides are widely applied to lands throughout the District. Pesticides detected at District projects over the past 5 years include: acetochlor, alachlor, atrazine, isopropalin, metolachlor, metribuzin, prometon, propazine, and trifluralin. Many of these pesticides do not have State or Federal numeric water quality criteria established.

1.5.6 URBANIZATION

Urbanization around many District reservoirs is occurring at a rapid pace. Reservoirs with urbanizing watersheds include Cherry Creek, Chatfield, and Bear Creek in the Denver, Colorado area; Holmes in the Lincoln, Nebraska area; and Ed Zorinsky, Glen Cunningham, Standing Bear, and Wehrspann in the Omaha, Nebraska area. Urbanization, to a much lesser degree, is occurring at other Corps projects in the District.

Construction methods used to develop urban areas disturb the land and allow sediment-laden runoff to impact nearby streams and lakes. Best management practices (BMPs) to minimize construction associated sedimentation damages are used ineffectively in many cases. BMPs to control the impact of construction practices include; sediment retention basins, phased “grading”, and runoff control (e.g. hay

bales, silt fences, vegetative ground cover, terracing, etc). Efforts need to be made to prevent sedimentation from off-project construction activities from causing impacts to District projects. This could be accomplished by the appropriate State, County, or City agencies working with developers.

Post-construction problems are commonly associated with storm drainage and urban pollution. The conversion of grasslands or forests to roads, rooftops, sidewalks, and other water impervious surfaces make stream flows more variable and increase the frequency of high flow events. In addition, pollutants associated with urban drainage can impact downstream water bodies. Storm sewer exits can be allowed on project lands provided detention in the form of ponds, swales, or wetlands exist on private property. A developer may be asked to construct a series of wetlands to slow downhill flows and provide time for bacterial die-off, chemical degradation, reduced flow rates, and sediment settling.

1.6 PRIORITIZATION OF DISTRICT-WIDE WATER QUALITY MANAGEMENT ISSUES

The District has identified seven priority issues for water quality management. These priority issues and their relative ranking are listed in Table 1.2.

1.7 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AT THE TRIBUTARY PROJECTS

1.7.1 SECTION 303(D) LISTINGS OF IMPAIRED WATERS

Under Section 303(d) of the Federal Clean Water Act (CWA), Tribes and States, with the delegated authority from the U.S. Environmental Protection Agency (EPA), are required to prepare a periodic list of impaired waters [i.e., Section 303(d) list]. Impaired waters refer to those water bodies where it has been determined that technology-based effluent limitations required by Section 301 of the CWA are not stringent enough to attain and maintain applicable water quality standards. Tribes and States, as appropriate, are required to establish and implement Total Maximum Daily Loads (TMDLs) for water bodies on their Section 303(d) lists.

Table 1.2. Priority water quality management issues within the Omaha District.

Ranking*	Water Quality Management Issue
1	Determine how regulation of the Missouri River Mainstem System (Mainstem System) dams affects water quality in the impounded reservoir and downstream river. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
2	Evaluate how eutrophication is progressing in the Mainstem System reservoirs, especially regarding the expansion of anoxic conditions in the hypolimnion during summer stratification.
3	Determine how the flow regime, especially the release of water from Mainstem System projects, affects water quality in the Missouri River.
4	Provide water quality information to support Corps reservoir regulation elements for effective surface water quality and aquatic habitat management.
5	Provide water quality information and technical support to the Tribes and States in the development of their Section 303(d) lists and development and implementation of TMDLs at District projects.
6	Identify existing and potential surface water quality problems at District projects, and develop and implement appropriate solutions.
7	Evaluate surface water quality conditions and trends at District projects.

* 1 = Highest priority, 7 = Lowest Priority

1.7.2 FISH CONSUMPTION ADVISORIES

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. The public has expressed concerns on whether fish caught from District project waters are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by States when considering the issuance of fish consumption advisories. Fish consumption advisories have been issued for fish caught from certain District project waters. Mercury is the most prevalent contaminant leading to the issuance of fish consumption advisories in the District.

1.7.3 SUMMARY OF PROJECT-SPECIFIC TMDL CONSIDERATIONS, FISH CONSUMPTION ADVISORIES, AND OTHER WATER QUALITY MANAGEMENT ISSUES

Table 1.3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Tributary Projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1.3 are taken directly from the appropriate State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1.3 were identified by the District based on water quality monitoring and water quality management concerns. Water quality management issues at specific Tributary projects are assessed in further detail in District Project Specific Reports (USACE, 2007a) that are prepared or State-prepared TMDL plans developed for any State-listed impaired water body.

Table 1.3. Summary of project-specific water quality management issues and concerns at District Tributary Projects.

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Water Quality Management Issues
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Colorado Tributary Projects:							
Bear Creek Reservoir	Yes	Aquatic Life	Dissolved Oxygen**	No	No		Site specific phosphorus and chlorophyll-a water quality criteria
Chatfield Reservoir	No	-----	-----	-----	No		Site specific phosphorus and chlorophyll-a water quality criteria
Cherry Creek Reservoir	Yes	Aquatic Life, Recreation	Chlorophyll-a, Dissolved Oxygen **	No	No		Site specific phosphorus and chlorophyll-a water quality criteria
Nebraska Tributary Projects:							
Bluestem Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a, Nitrogen, Phosphorus, Sediment, Selenium	No	No		Algal blooms
Branched Oak Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a	No	No		
Conestoga Reservoir	Yes	Aesthetics, Aquatic Life	Algae Toxins, Chlorophyll-a, Nitrogen, Phosphorus, Sediment, Selenium	No	No		Algal blooms Cyanobacteria toxins
East Twin Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a, Phosphorus, Sediment, Selenium	No	No		Algal blooms
Ed Zorinsky Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a, Mercury (Fish Tissue)	Yes/No	Yes	Mercury	TMDLs for dissolved oxygen, nutrients, and sediment approved (2002)
Glenn Cunningham Reservoir	Yes	Aesthetics, Aquatic Life	Nitrogen, Phosphorus, Sediment, Selenium	No	No		Lake renovation project being implemented
Holmes Reservoir	No	-----	Nutrients, Sediment	Yes	No		TMDLs for nutrients and sediment approved (2003)
Olive Creek Reservoir	Yes	Aesthetics Aquatic Life	Ammonia, Arsenic, Chlorophyll-a, Nitrogen, pH, Phosphorus	No	No		Algal blooms
Pawnee Reservoir	Yes	Aesthetics, Aquatic Life, Recreation	Algae Toxins, Arsenic, Chlorophyll-a	Yes/No	No		TMDL for sediment approved (2001) Algal blooms, Cyanobacteria toxins
Stagecoach Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a, Phosphorus	No	No		Algal blooms
Standing Bear Reservoir	Yes	Aesthetics, Aquatic Life	Chlorophyll-a, Mercury (Fish Tissue), Sediment, Selenium	Yes/No	Yes	Mercury	TMDLs for sediment, dissolved oxygen, and nutrients approved (2003)
Wagon Train Reservoir	No	-----	Arsenic, Chlorophyll-a, Nitrogen, Phosphorus	Yes	No		TMDLs for sediment, dissolved oxygen, and nutrients approved (2002) Arsenic – Natural conditions
Wehrspann Reservoir	Yes	Aesthetics Aquatic Life	Chlorophyll-a, Mercury (Fish Tissue), Phosphorus	No	Yes	Mercury	Algal blooms
West Twin Reservoir	Yes	Aquatic Life, Aesthetics	Ammonia, Chlorophyll-a, Nitrogen, Phosphorus, Sediment, Selenium	No	No		Algal blooms
Yankee Hill Reservoir	No	-----	Nutrients, sediment	Yes	No		TMDLs for nutrients and sediment approved (2003)
North Dakota Tributary Projects:							
Bowman-Haley Reservoir	No	-----	-----	-----	Yes	Mercury	Algal blooms
Pipestem Reservoir	Yes	Recreation	Nutrients/Eutrophication	No	Yes	Mercury	Algal blooms
South Dakota Tributary Projects:							
Cold Brook	Yes	Coldwater Fishery	Water Temperature	No	No		

* Information taken from published State Total Maximum Daily Load (TMDL) Section 303(d) reports and listings.
** Identified on Colorado's Monitoring and Evaluation List. Water quality problem suspected, but uncertainty exists based on available data.

2 LIMNOLOGICAL PROCESSES IN RESERVOIRS

Many of the Corps civil works projects in the District involve the operation and maintenance of a reservoir or the regulation of flows discharged from reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. The following discussion provides a basic overview of limnological processes that occur in reservoirs.

2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

<u>Epilimnion</u>: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

<u>Metalimnion</u>: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

<u>Hypolimnion</u>: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs, with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

<u>Riverine Zone:</u> The riverine zone is relatively narrow, well mixed, and although water current velocities are decreasing, advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

<u>Zone of Transition:</u> Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a

compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than “natural” lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.1 CONSTITUENTS

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of water bodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2.1). Density interflows not only transport oxygen-demanding material into the metalimnion, but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion

for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

Dissolved oxygen distribution: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2.1). In the orthograde distribution, DO concentration is a function primarily of temperature, since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

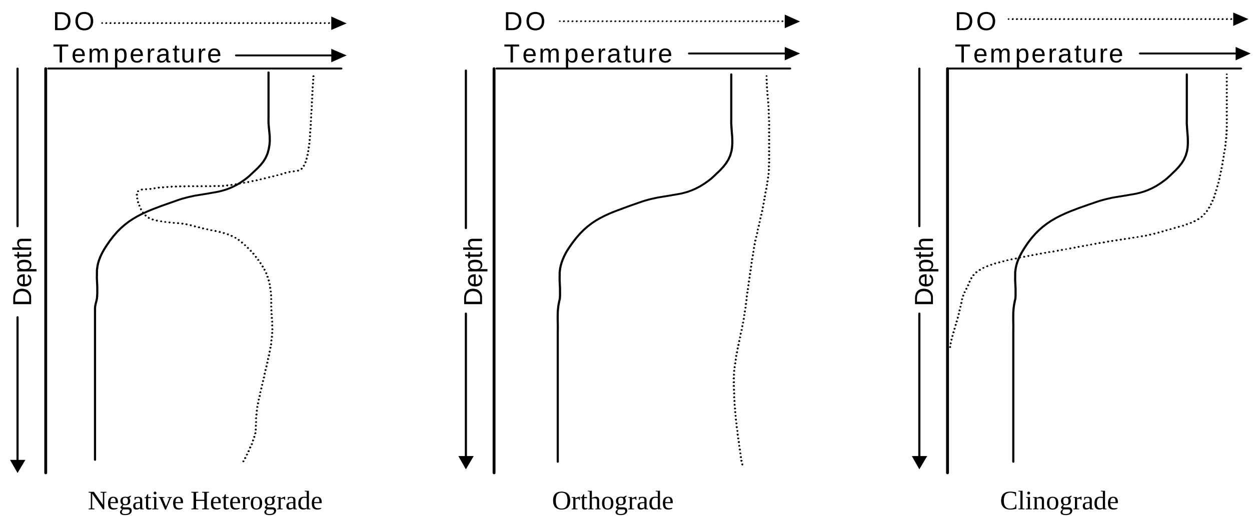

Figure 2.1. Vertical oxygen concentrations possible in thermally stratified lakes.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH $\approx$ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite

(NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form besides NH_3 used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2 ANAEROBIC (ANOXIC) CONDITIONS

When dissolved oxygen concentrations in the hypolimnion are reduced to approximately 2 to 3 mg/l, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e., Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form, and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species so the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic

matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs (carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or through entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.3.1 MICROBIOLOGICAL

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.3.2 PHOTOSYNTHESIS

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.3.3 PLANKTON

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives.

Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.3.4 ORGANIC CARBON AND DETRITUS

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant affect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

3 TRIBUTARY PROJECTS WATER QUALITY MONITORING

3.1 COLORADO TRIBUTARY RESERVOIRS

The District has not conducted water quality monitoring at any of the three District project reservoirs in Colorado since 2002. At each of these reservoirs (i.e., Bear Creek, Chatfield, and Cherry Creek), local Watershed Authorities have been established to improve and protect water quality. As part of these efforts, the Watershed Authorities have established extensive water quality monitoring networks at each of the three reservoirs. After reviewing the water quality monitoring efforts of the three Watershed Authorities, the District felt that its water quality information needs can be met though the use of the water quality data collected through the efforts of the Watershed Authorities. Assessments of recent water quality conditions at the three Colorado project reservoirs are deferred to the local Watershed Authorities.

3.2 NEBRASKA TRIBUTARY RESERVOIRS

3.2.1 AMBIENT WATER QUALITY MONITORING

The District has conducted fixed station ambient monitoring at the Nebraska tributary reservoirs. Some reservoirs have been monitored over the past 30 years. Since 2003, the Omaha District has cooperated with the Nebraska Department of Environmental Quality (NDEQ) to monitor ambient water quality conditions at all the Papillion Creek tributary reservoirs (i.e., Glenn Cunningham, Standing Bear, Wehrspann, and Ed Zorinsky) and Salt Creek tributary reservoirs (i.e., Bluestem, Branched Oak, Conestoga, East Twin, Holmes, Olive Creek, Pawnee, Stagecoach, Wagon Train, West Twin, and Yankee Hill). Recent water quality monitoring was curtailed at the Glen Cunningham, Holmes and Yankee Hill Reservoirs due to draw-downs for lake renovations.

Ambient water quality monitoring at the Nebraska tributary reservoirs included monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location included field measurements for depth profiling and water transparency, and collection of near-surface and near-bottom grab samples for laboratory analysis. Water quality monitoring at the mid-reservoir location included field measurements for depth profiling and water transparency. Depth profiles in ½-meter increments were determined for temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a*. Near-surface grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, chlorophyll *a*, pesticides, and various metals. Except for chlorophyll *a*, pesticides, and various metals, near-bottom samples grab samples were analyzed for the same parameters.

3.2.2 MONITORING AT SWIMMING BEACHES

The Omaha District has cooperated with the NDEQ to monitor bacteria and cyanobacteria toxin levels present at swimming beaches and major recreational use areas at the Nebraska tributary reservoirs over the past 5 years. Reservoirs that were sampled include: Glenn Cunningham, Bluestem, Branched Oak, Conestoga, Pawnee, and Wagon Train. Weekly grab samples were collected from May to September and analyzed for fecal coliform and *E. coli* bacteria and the cyanobacterial toxin microcystins. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.2.3 INFLOW MONITORING DURING RUNOFF CONDITIONS

Since 2003, the District has cooperated with the NDEQ to monitor water quality conditions of major inflows under runoff conditions at all the Nebraska tributary reservoirs. Up to six runoff events from April through September were sampled annually at each of the reservoirs. Near-surface runoff grab samples were collected from a bridge or stream bank and analyzed for suspended solids, total Kjeldahl nitrogen, nitrate/nitrate, total ammonia, total phosphorus, alachlor, atrazine, and metolachlor.

3.3 NORTH DAKOTA TRIBUTARY RESERVOIRS

The District has monitored ambient water quality conditions over the past 30 years at the two Corps tributary reservoirs in North Dakota – Bowman-Haley and Pipestem. During the past 5 years, ambient monitoring was conducted in 2002, 2003, and 2004. Ambient water quality monitoring at Bowman-Haley and Pipestem Reservoirs is now on a 3-year rotating cycle with the next ambient monitoring scheduled for 2007. The ambient monitoring included monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location included field measurements for depth profiling and water transparency and collecting near-surface and near-bottom water samples for laboratory physicochemical analysis. Water quality monitoring at the mid-reservoir location included field measurements for depth profiling and water transparency. Depth profiles in 1/2-meter increments were determined for temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity. Near-surface grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals. Except for chlorophyll *a*, pesticides, and various metals, near-bottom samples grab samples were analyzed for the same parameters.

3.4 SOUTH DAKOTA TRIBUTARY RESERVOIRS

The District has monitored ambient water quality conditions at the two Corps tributary reservoirs in South Dakota – Cold Brook and Cottonwood Springs. During the past 5 years, the District conducted water quality monitoring at these reservoirs in 2002, and 2003. Ambient water quality monitoring at the two reservoirs is now on a 3-year rotating cycle with the next ambient monitoring scheduled for 2008. Ambient water quality monitoring was scheduled for 2005, but was cancelled due low water conditions and access problems. Scheduled ambient water quality monitoring includes monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location includes field measurements for depth profiling and water transparency and collecting near-surface and near-bottom water samples for laboratory physicochemical analysis. Water quality monitoring at the mid-reservoir location includes field measurements for depth profiling and water transparency. Depth profiles in ½-meter increments are determined for temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity. Near-surface grab samples are analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals. Except for chlorophyll *a*, pesticides, and various metals, near-bottom samples grab samples are analyzed for the same parameters.

4 WATER QUALITY ASSESSMENT METHODS

4.1 EXISTING WATER QUALITY (2002 THROUGH 2006)

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2002 through 2006). Water quality monitoring conducted during that period was used to describe existing water quality conditions.

4.1.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

Statistical analyses were performed on the water quality monitoring data collected at the Tributary Projects. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal CWA. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.1.2 SPATIAL VARIATION IN WATER QUALITY CONDITIONS

4.1.2.1 <u>Longitudinal Variation</u>

Depending on their length, shape, mixing characteristics, and residence time, reservoirs can experience significant longitudinal variation in water quality. The longitudinal variation is largely dependent on inflow water quality characteristics.

4.1.2.1.1 Reservoir Contour Plots

Longitudinal contour plots were constructed when adequate depth-profile measurements were collected along the length of a reservoir. Adequate information was collected in 2006 to construct longitudinal contour plots at the Papillion Creek and Salt Creek Reservoirs in Nebraska. At these reservoirs longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic, Inc. (Hydrogeologic Inc., 2005).

4.1.2.1.2 Reservoir Box Plots

Longitudinal box plots were constructed when adequate measurements were collected along the length of a reservoir. Box plots were constructed for measured Secchi depths.

4.1.2.2 <u>Vertical Variation in Reservoir Water Quality</u>

Depending on their depth and bathymetry, reservoirs can experience thermally-induced density stratification in the summer. This can lead to vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion.

4.1.2.2.1 Summer Depth Profile Plots

Measured water temperature and dissolved oxygen depth profiles were plotted. The plotted depth profiles were measured at the near-dam, deepwater ambient monitoring location. Depth profiles measured during the summer over the past 5 years were included. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

4.1.2.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

The variation of selected parameters with depth was evaluated by comparing paired near-surface and near-bottom collected samples. The compared paired samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, and various nutrients.

4.1.3 TROPHIC STATUS

A trophic state index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$TSI(\text{Secchi Depth}) = TSI(SD) = 10[6 - (\ln SD/\ln 2)]$$
$$TSI(\text{Chlorophyll } a) = TSI(Chl) = 10[6 - ((2.04-0.68 \ln Chl)/\ln 2)]$$
$$TSI(\text{Total Phosphorus}) = TSI(TP) = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi depth transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. Carlson states that care must be taken if a TSI average score is calculated from the three individual parameter TSI values. If significant differences exist between parameter TSI values, the calculated average value may not be indicative of the trophic condition estimated by the individual parameter values. With this consideration, a TSI average value [TSI(Avg)] calculated as the average of the three individually determined TSI values [i.e., TSI(SD), TSI(Chl), and TSI(TP)] is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4.1 for determining lake trophic status from TSI values.

Table 4.1. Lake trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

4.1.4 ATTAINMENT OF WATER QUALITY STANDARDS

The attainment of water quality standards was assessed by determining the support of designated water quality beneficial uses. Where applicable water quality standards criteria existed, beneficial support was determined by the number of times the criteria were exceeded during the 5-year period of 2002 through 2006 based on water quality monitoring conducted by the District. The following water quality standards attainment ratings were defined: 1) Full Support (less than 10% of the observations exceed criteria), 2) Not Supported (greater than 20% of the observations exceed criteria), and 3) Partially Supported (10-20% of observations exceed criteria or greater 10% of the observations exceed criteria seasonally). It is noted that the “official” determination of whether water quality standards are being attained, pursuant to the Federal CWA, is identified by the States pursuant to their Section 305(b) and Section 303(d) assessments (See Table 1.3).

4.2 WATER QUALITY TRENDS

Surface water quality trends were assessed by evaluating water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a* and calculated TSI(Avg) values from monitoring results obtained at long-term, fixed-station ambient monitoring sites for the period 1980 to 2006.

5 COLORADO TRIBUTARY PROJECTS

Three District tributary reservoir projects are located in north-central Colorado: Bear Creek, Chatfield, and Cherry Creek (Figure 1.1). The three projects are commonly referred to as the Colorado Tri-Lakes Projects. All three reservoirs are located in the Denver, Colorado metropolitan area (Figure 5.1). Table 5.1 gives selected engineering data for the Colorado Tri-Lakes Projects.

5.1 BEAR CREEK RESERVOIR

5.1.1 Background Information

5.1.1.1 Project Overview

The dam forming Bear Creek Reservoir is located on Bear Creek, 3 miles southwest of Denver, Colorado (Figure 5.1). The dam was completed in July 1977 and the reservoir reached its initial fill in May 1979. The Bear Creek Reservoir watershed is 236 square miles. The watershed was rangeland, forested, and residential/acreage development when the dam was built in 1974. Urbanization of the watershed is occurring with the growth of the Denver metropolitan area. The authorized project purposes for Bear Creek Reservoir are: flood control, recreation, and fish and wildlife. An upgraded aeration system was installed in Bear Creek Reservoir in 2002 to improve water quality.

5.1.1.2 Bear Creek Dam Intake Structure

The outlet works at Bear Creek Dam consist of a reinforced concrete intake structure with high-level drop inlets and a low-level 36-inch diameter reinforced concrete pipe and intake upstream of the intake structure. The gate structure is contained in the dam just upstream of the impervious core. The high-level drop inlets have two weirs at elevation 5558.0 ft-msl (multipurpose pool level). Two lower-level gated inlets are located at invert elevations of 5538.0 and 5528.0 ft-msl. The low-level intake at elevation 5528.0 ft-msl is 135 feet upstream from the main intake structure.

5.1.1.3 Reservoir Storage Zones

Figure 5.2 depicts the current storage zones of Bear Creek Reservoir based on the 1997 survey data and estimated sedimentation. It is estimated that 7 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

5.1.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

The State of Colorado's water quality standards designate the following beneficial uses to Bear Creek Reservoir: primary contact recreation, domestic water supply, Class 1 coldwater aquatic life, and agriculture. Pursuant to Section 303(d) of the CWA, the State of Colorado has placed Bear Creek Reservoir on the State's 303(d) list of impaired waters (Table 1.3). Bear Creek Reservoir is listed for impairment to aquatic life due to low dissolved oxygen. The State of Colorado has not issued a fish consumption advisory for Bear Creek Reservoir.

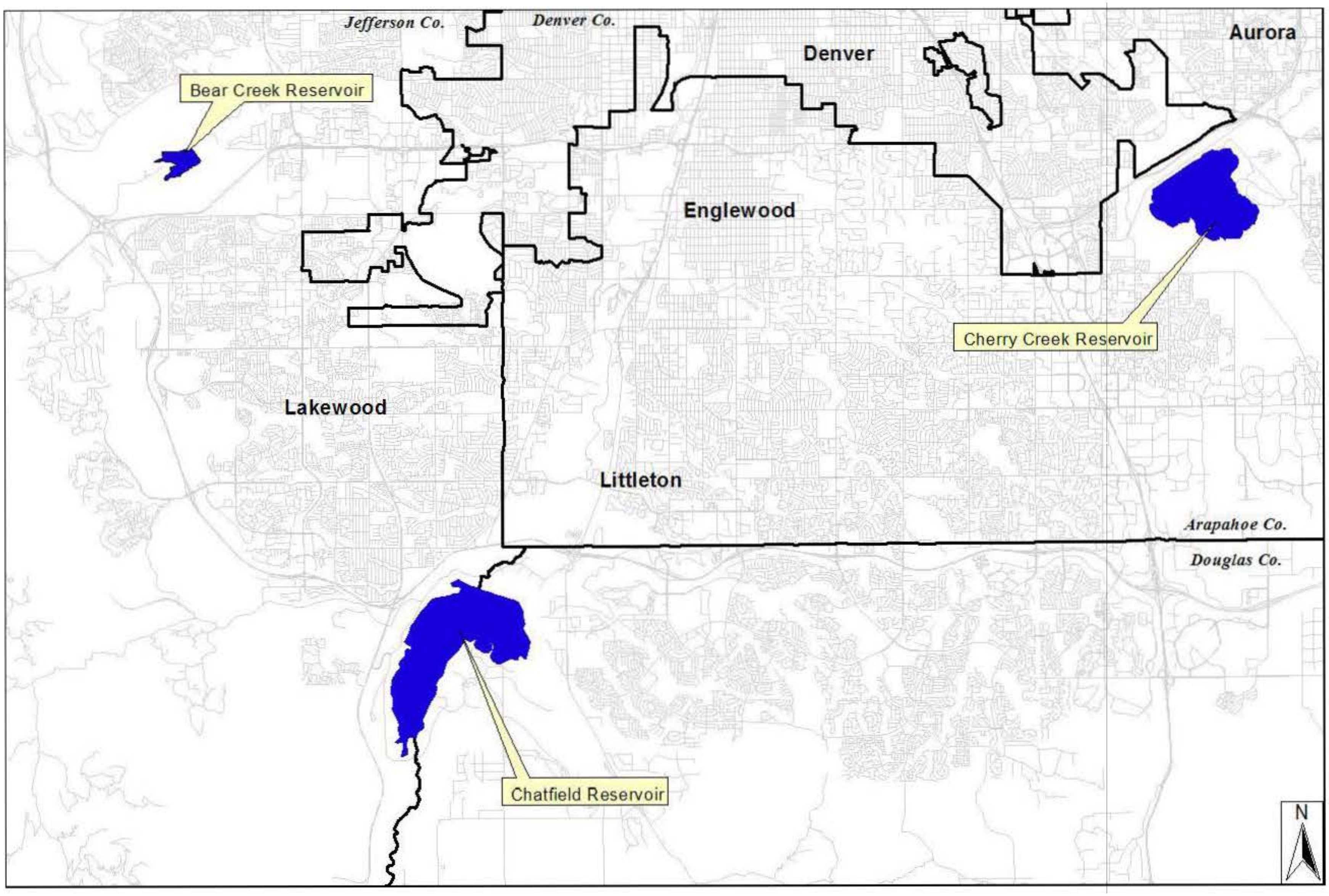

Figure 5.1. Locations of Bear Creek, Chatfield, and Cherry Creek Reservoirs in the Denver, Colorado metropolitan area.

Table 5.1. Summary of selected engineering data for the Colorado Tri-Lakes Tributary Projects.

	Beak Creek Reservoir	Chatfield Reservoir	Cherry Creek Reservoir
General			
Dammed Stream	Bear Creek	South Platte River	Cherry Creek
Drainage Area	236 sq mi	3,018 sq mi	386 sq mi
Reservoir Length[1]	0 5 miles	2 0 miles	1 5 miles
Multipurpose Pool Elevation (Top)	5558 0 ft-msl	5,432 0 ft-msl	5550 0 ft-msl
Date of Dam Closure	July 1977	August 1973	October 1948
Date of Initial Fill[2]	May 1979	June 1979	March 1960
"As-Built" Conditions[3]	(1980 Survey Data)	(1977 Survey Data)	(1950 Survey Data)
Lowest Reservoir Bottom Elevation	5517 ft-msl	5379 ft-msl	5504 ft-msl
Surface Area at top of Multipurpose Pool	109 ac	1,444 ac	886 ac
Capacity of Multipurpose Pool	1,964 ac-ft	28,076 ac-ft	15,155 ac-ft
Mean Depth at top of Multipurpose Pool[4]	18 0 ft	19 4 ft	17 1 ft
Latest Surveyed Conditions	(1997 Survey Data)	(1998 Survey Data)	(1988 Survey Data)
Lowest Reservoir Bottom Elevation	5520 ft-msl	5380 ft-msl	5523 ft-msl
Surface Area at top of Multipurpose Pool	106 ac	1,429 ac	847 ac
Capacity of Multipurpose Pool	1,882 ac-ft	27,428 ac-ft	12,805 ac-ft
Mean Depth at top of Multipurpose Pool[5]	17 8 ft	19 2 ft	15 1 ft
Sediment Deposition in Multipurpose Pool			
Historic Sediment Deposition[6]	82 ac-ft	648 ac-ft	2,350 ac-ft
Annual Sedimentation Rate[7]	1980-1997 4 6 ac-ft/yr	1977-1998 29 5 ac-ft/yr	1950-1988 60 3 ac-ft/yr
Current Estimated Sediment Deposition[8]	123 ac-ft	884 ac-ft	3,496 ac-ft
Current capacity of Multipurpose Pool[9]	1,841 ac-ft	27,192 ac-ft	11,720 ac-ft
Percent of "As-Built" Multipurpose Pool capacity lost to current estimated sediment deposition	6%	3%	23%
Operational Details – Historic	(1980 – 2006)	(1980 – 2006)	(1958 – 2006)
Maximum Recorded Pool Elevation	5587 1 ft-msl 18-Jun-95	5447 6 ft-msl 26-May-80	5565 8 ft-msl 3-Jun-73
Minimum Recorded Pool Elevation	5549 2 ft-msl 18-Oct-99	5423 0 ft-msl 30-Aug-03	5543 5 ft-msl 29-Jan-65
Maximum Recorded Daily Inflow	910 cfs 1-May-80	3,394 cfs 2-Jul-95	6,150 cfs 16-Jun-65
Maximum Recorded Daily Outflow	800 cfs 5-May-80	3,350 cfs 7-Jul-95	560 cfs 7-Aug-65
Average Annual Pool Elevation	5558 7 ft-msl	5430 1 ft-msl	5549 2 ft-msl
Average Annual Inflow	36,031 ac-ft	153,578 ac-ft	10,556 ac-ft
Average Annual Outflow	35,696 ac-ft	151,516 ac-ft	7,354 ac-ft
Estimated Retention Time[10]	0 05 Years	0 18 Years	1 59 Years
Operational Details – Current[11]			
Maximum Recorded Pool Elevation	5559 3 ft-msl 9-Jul-06	5432 6 ft-msl 10-Jul-06	5550 3 ft-msl 14-Dec-05
Minimum Recorded Pool Elevation	5555 2 ft-msl 18-Sep-06	5423 2 ft-msl 29-Sep-06	5548 0 ft-msl 7-Sep-06
Maximum Recorded Daily Inflow	146 cfs 10Jul-06	878 cfs 10-Jul-06	164 cfs 2-Aug-06
Maximum Recorded Daily Outflow	146 cfs 10-Jul-06	895 cfs 11-Jul-06	61 cfs 13-Jul-06
Total Inflow (% of Normal)	8,850 ac-ft (25%)	76,666 ac-ft (51%)	12,193 ac-ft (119%)
Total Outflow (% of Normal)	8,672 ac-ft (25%)	78,380 ac-ft (54%)	10,423 ac-ft (143%)
Outlet Works			
Ungated Outlets	Drop Inlet 5558 0 ft-msl		2) 1 0'x2 5' 1104 0 ft-msl 2) 2 0'x6 0' 1109 0 ft-msl
Gated Outlets (Mid-depth)	2) 3' x 6' hydraulic slide 1) 36" Dia 5538 0 ft-msl	2) 6' x 13 5' hydraulic slide 2) 2' x 2' slide gate on gate 1) 6' butterfly	5) 6' x 9' hydraulic slide
Gated Outlets (Low-level)	1) 36" Dia 5528 0 ft-msl	none	2) 18" by-pass gates

(1) Reservoir length at top of conservation pool
(2) First occurrence of reservoir pool elevation to top of multipurpose pool elevation
(3) "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
(4) Mean Depth = Volume ÷ Surface Area
(5) Difference in reservoir storage capacity to top of Multipurpose Pool between "as-built" and latest survey
(6) Annualized rate based on historic accumulated sediment
(7) Current accumulated sediment estimated from historic annual sedimentation rate
(8) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
(9) Reservoir drawn down for lake restoration project
(10) Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
(11) Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

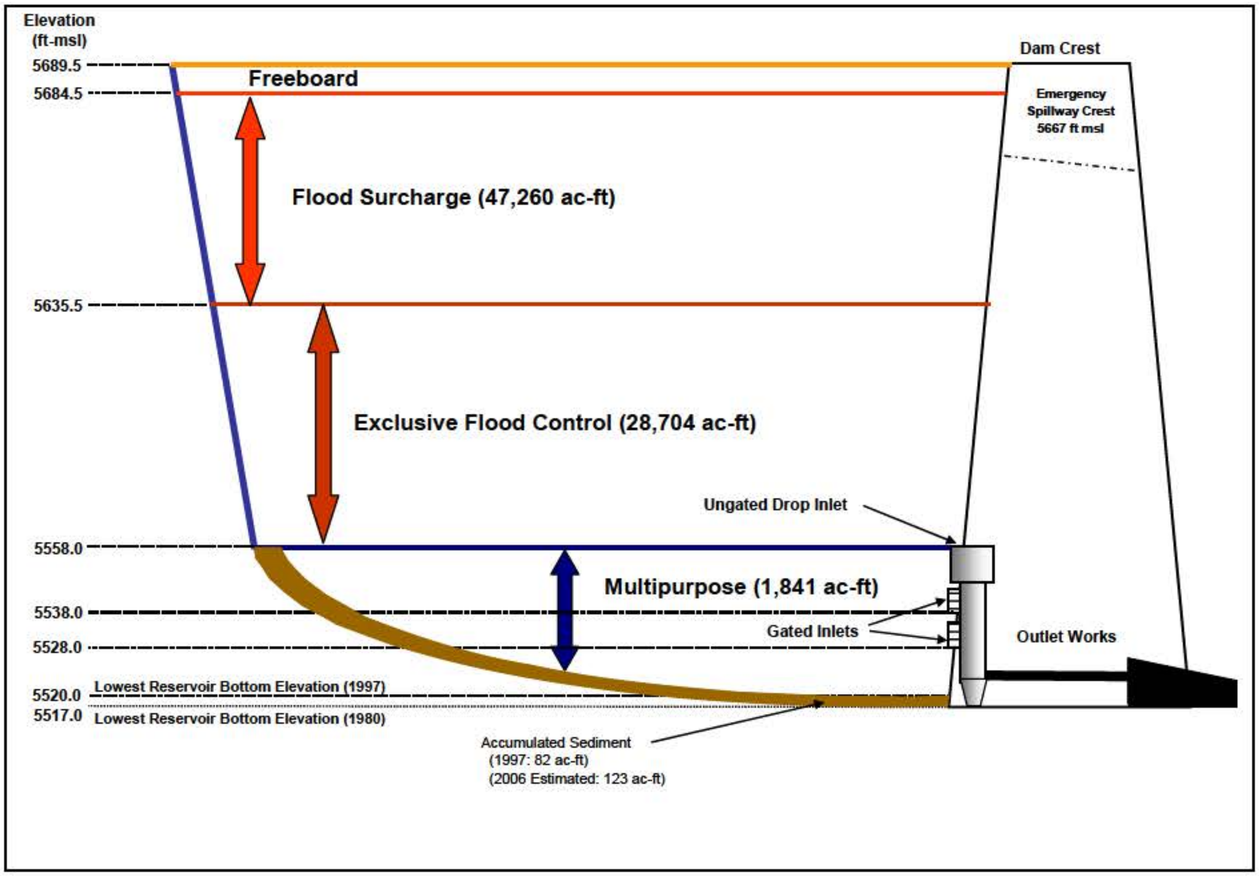

Figure 5.2. Current storage zones of Bear Creek Reservoir based on the 1997 survey data and estimated sedimentation.

5.1.1.5 Ambient Water Quality Monitoring

A Local Watershed Authority has been established for Bear Creek Reservoir to protect and improve water quality at the reservoir. The Bear Creek Watershed Authority has adopted local water quality regulations and a water quality management plan to protect and manage water quality in Bear Creek Reservoir. As part of its water quality management plan, the Bear Creek Watershed Authority is implementing a comprehensive water quality monitoring program. For efficiency purposes, the District ceased its water quality monitoring activities at Bear Creek Reservoir in 2002, and now defers to the Bear Creek Watershed Authority for assessment of water quality conditions at Bear Creek Reservoir. Prior to 2002, the District had monitored water quality at Bear Creek Reservoir since the 1970's.

5.1.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

Persons interested in existing water quality conditions at Bear Creek Reservoir can visit the website maintained by the Bear Creek Watershed Association (http://www.bearcreekwatershed.org).

5.2 CHATFIELD RESERVOIR

5.2.1 BACKGROUND INFORMATION

5.2.1.1 Project Overview

The dam forming Chatfield Reservoir is located on the South Platte River, 2 miles south of Denver, Colorado (Figure 5.1). The dam was completed in August 1973 and the reservoir reached its initial fill in June 1979. The Chatfield Reservoir watershed is 3,018 square miles. The watershed was rangeland, forested, and residential/acreage development when the dam was built in 1973. Urbanization of the watershed is occurring with the growth of the Denver metropolitan area. The authorized project purposes for Chatfield Reservoir are: flood control, recreation, fish and wildlife, and water supply.

5.2.1.2 Chatfield Dam Intake Structure

The intake structure has three gated passageways which conduct water to a twin conduit. The two right passageways have a service and emergency gate which are controlled by hydraulic hoists. In each gate a 2-foot x 2-foot auxiliary gate is provided to facilitate regulation of normal flows to the river. In the left passageway of the intake structure is a 6-foot diameter penstock, equipped with a butterfly valve near the upstream end, is provided to conduct releases to satisfy the downstream water rights.

5.2.1.3 Reservoir Storage Zones

Figure 5.3 depicts the current storage zones of Chatfield Reservoir based on the 1998 survey data and estimated sedimentation. It is estimated that 3 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

5.2.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

The State of Colorado's water quality standards designate the following beneficial uses to Chatfield Reservoir: primary contact recreation, domestic water supply, Class 1 coldwater aquatic life, and agriculture. Chatfield Reservoir is a source of public drinking water for the Cities of Denver, Englewood, and Littleton, Colorado. Pursuant to Section 303(d) of the CWA, the State of Colorado has not placed Chatfield Reservoir on the State's 303(d) list of impaired waters. The State of Colorado has not issued a fish consumption advisory for Chatfield Reservoir.

5.2.1.5 Ambient Water Quality Monitoring

A Local Watershed Authority has been established for Chatfield Reservoir to protect and improve water quality at the reservoir. The Chatfield Watershed Authority has adopted local water quality regulations and a water quality management plan to protect and manage water quality in Chatfield Reservoir. As part of its water quality management plan, the Chatfield Watershed Authority is implementing a comprehensive water quality monitoring program. For efficiency purposes, the District ceased its water quality monitoring activities at Chatfield Reservoir in 2002, and now defers to the Chatfield Watershed Authority for assessment of water quality conditions at Chatfield Reservoir. Prior to 2002, the District had monitored water quality at Chatfield Reservoir since the 1970's.

5.2.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

Persons interested in existing water quality conditions at Chatfield Reservoir can visit the website maintained by the Chatfield Watershed Association (http://www.chatfieldwatershed.org).

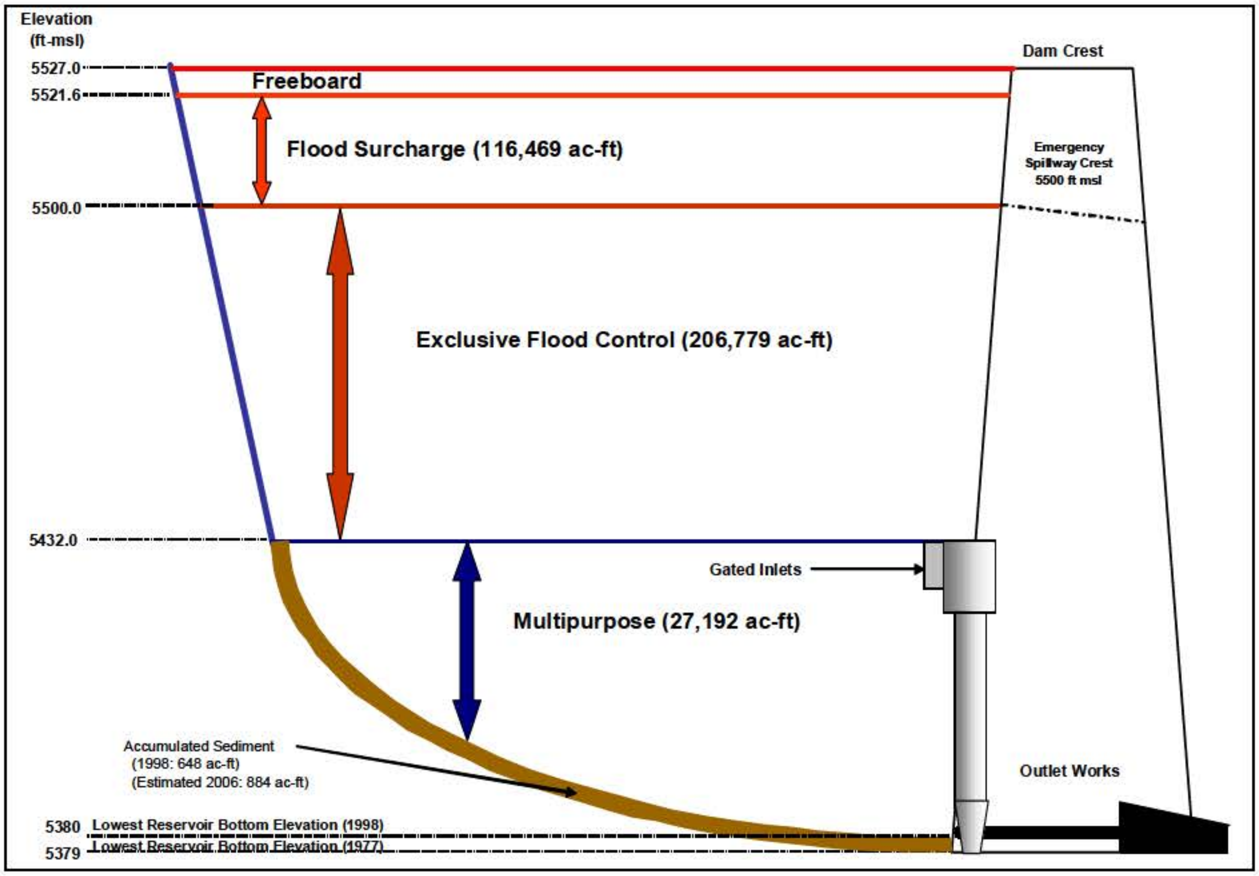

Figure 5.3. Current storage zones of Chatfield Reservoir based on the 1998 survey data and estimated sedimentation.

5.3 CHERRY CREEK RESERVOIR

5.3.1 BACKGROUND INFORMATION

5.3.1.1 Project Overview

The dam forming Cherry Creek Reservoir is located on Cherry Creek, southeast of Denver, Colorado (Figure 5.1). The dam was completed in October 1948 and the reservoir reached its initial fill in March 1960. The Cherry Creek Reservoir watershed is 386 square miles. The watershed was rangeland and agricultural when the dam was built in 1948. Extensive urbanization of the watershed has occurred with the growth of the Denver metropolitan area. The authorized project purposes for Cherry Creek Reservoir are: flood control, recreation, and fish and wildlife.

5.3.1.2 Cherry Creek Dam Intake Structure

The Cherry Creek Dam intake tower contains five rectangular water passages with a 6' x 9' slide gate in each to control water flow. Two emergency gates have also been added to the intake structure. These gates can be installed while water is flowing thru a water passage, but are not to be used for regulating flow. A low-flow by-pass was installed in February 1988 to allow finer regulation of flow to downstream water rights users. The low-flow by-pass consists of two 18" knife values.

5.3.1.3 Reservoir Storage Zones

Figure 5.4 depicts the current storage zones of Cherry Creek Reservoir based on the 1988 survey data and estimated sedimentation. It is estimated that 19 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

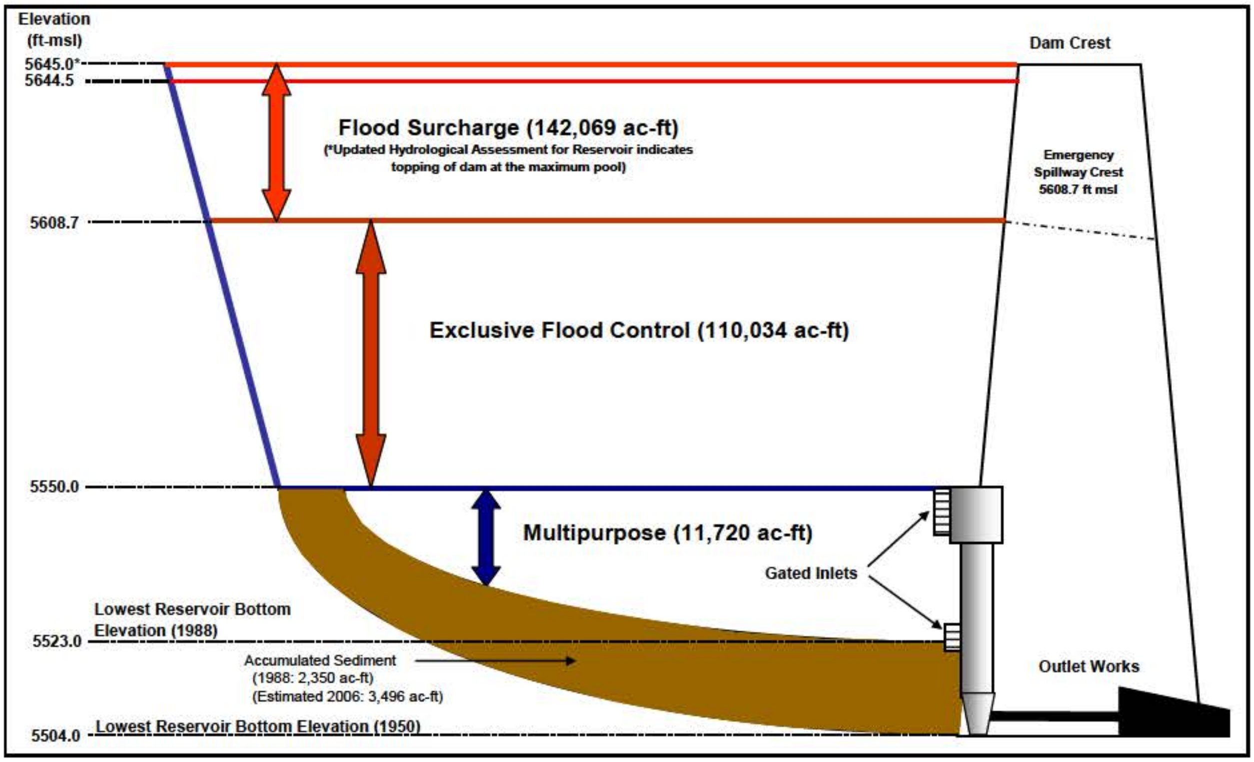

Figure 5.4. Current storage zones of Cherry Creek Reservoir based on the 1988 survey data and estimated sedimentation.

5.3.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

The State of Colorado's water quality standards designate the following beneficial uses to Cherry Creek Reservoir: primary contact recreation, domestic water supply, Class 1 warmwater aquatic life, and agriculture. Pursuant to Section 303(d) of the CWA, the State of Colorado has placed Cherry Creek Reservoir on the State's 303(d) list of impaired waters. Cherry Creek Reservoir is listed for impairment to the uses of aquatic life and primary contact recreation due to elevated chlorophyll *a* levels resulting from high phosphorus loadings to the reservoir. The State of Colorado has not issued a fish consumption advisory for Cherry Creek Reservoir.

5.3.1.5 Ambient Water Quality Monitoring

A Local Watershed Authority has been established for Cherry Creek Reservoir to protect and improve water quality at the reservoir. The Cherry Creek Basin Watershed Authority has adopted local water quality regulations and a water quality management plan to protect and manage water quality in Cherry Creek Reservoir. As part of its water quality management plan, the Cherry Creek Basin Watershed Authority is implementing a comprehensive water quality monitoring program. For efficiency purposes, the District ceased its water quality monitoring activities at Cherry Creek Reservoir in 2002, and now defers to the Cherry Creek Basin Watershed Authority for assessment of water quality conditions at Cherry Creek Reservoir. Prior to 2002, the District had monitored water quality at Cherry Reservoir since the 1970's.

5.3.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

Persons interested in existing water quality conditions at Cherry Creek Reservoir can visit the website maintained by the Cherry Creek Basin Watershed Authority (http://www.cherrycreekbasin.org).

6 NEBRASKA TRIBUTARY PROJECTS

Tributary projects in Nebraska occur in two primary watersheds in the southeast area of the State: Papillion Creek in the Omaha area and Salt Creek in the Lincoln area (Figure 1.1).

6.1 PAPILLION CREEK TRIBUTARY PROJECTS

6.1.1 BACKGROUND INFORMATION

6.1.1.1 Papillion Creek Watershed Hydrology

Streamflow in the Papillion Creek watershed follows a characteristic pattern. Flows are generally low except for brief periods of rise caused by runoff from rainfall events. A snowpack over the basin in early spring can produce a significant rise in flow as a result of snowmelt runoff. During the winter months, streams in the basin are generally frozen over.

6.1.1.2 Tributary Project Reservoirs

Four District tributary reservoirs (Ed Zorinsky, Glenn Cunningham, Standing Bear, and Wehrspann) are located in the Omaha, Nebraska vicinity in the Papillion Creek watershed (Figure 6.1). The authorized purposes for the four reservoirs are flood control, recreation, fish and wildlife, and water quality. Table 6.1 gives selected engineering data for each of the four reservoir projects. A low-level outlet is installed at each dam to permit draining of the multipurpose pools in approximately a one month time period. This outlet may also be used to hasten the evacuation of flood storage so as to avoid damage to shoreline grasses and recreational facilities. The low-level outlet may also be used for water quality management purposes by providing downstream low flow augmentation releases and targeted reservoir water withdrawal.

6.1.1.2.1 Water Quality Standards Classifications and Section 303(d) Listings

The State of Nebraska's water quality standards designates the following beneficial uses to all the Papillion Creek tributary project reservoirs: recreation, warmwater aquatic life, agricultural water supply, and aesthetics. None of these reservoirs are used as a public drinking water supply or have designated swimming beaches. The State's water quality standards also identify nutrient criteria for lakes and impounded waters based on the categorization of the physical, chemical, and biological characteristics of the waterbody. Under this categorization, Ed Zorinsky, Standing Bear, and Wehrspann Reservoirs have been included in a common group coded as R13 impounded waters. Glenn Cunningham Reservoir is included in another grouping coded as R14 impounded waters.

Pursuant to the Federal CWA, the State of Nebraska has listed all the Papillion Creek Tributary project reservoirs as "Category 5" waters on the State's 2006 Section 303(d) list (see Table 1.3). A "Category 5" listing infers that at least one beneficial use is impaired and a TMDL is required. The beneficial use identified as impaired is aquatic life. The identified pollutants/stressors include: sedimentation (Glenn Cunningham Reservoir) and mercury (Ed Zorinsky, Standing Bear, and Wehrspann Reservoirs). The State of Nebraska has issued fish consumption advisories for Ed Zorinsky, Standing Bear, and Wehrspann Reservoirs due to mercury concerns. TMDLs have been completed for Ed Zorinsky and Standing Bear Reservoirs.

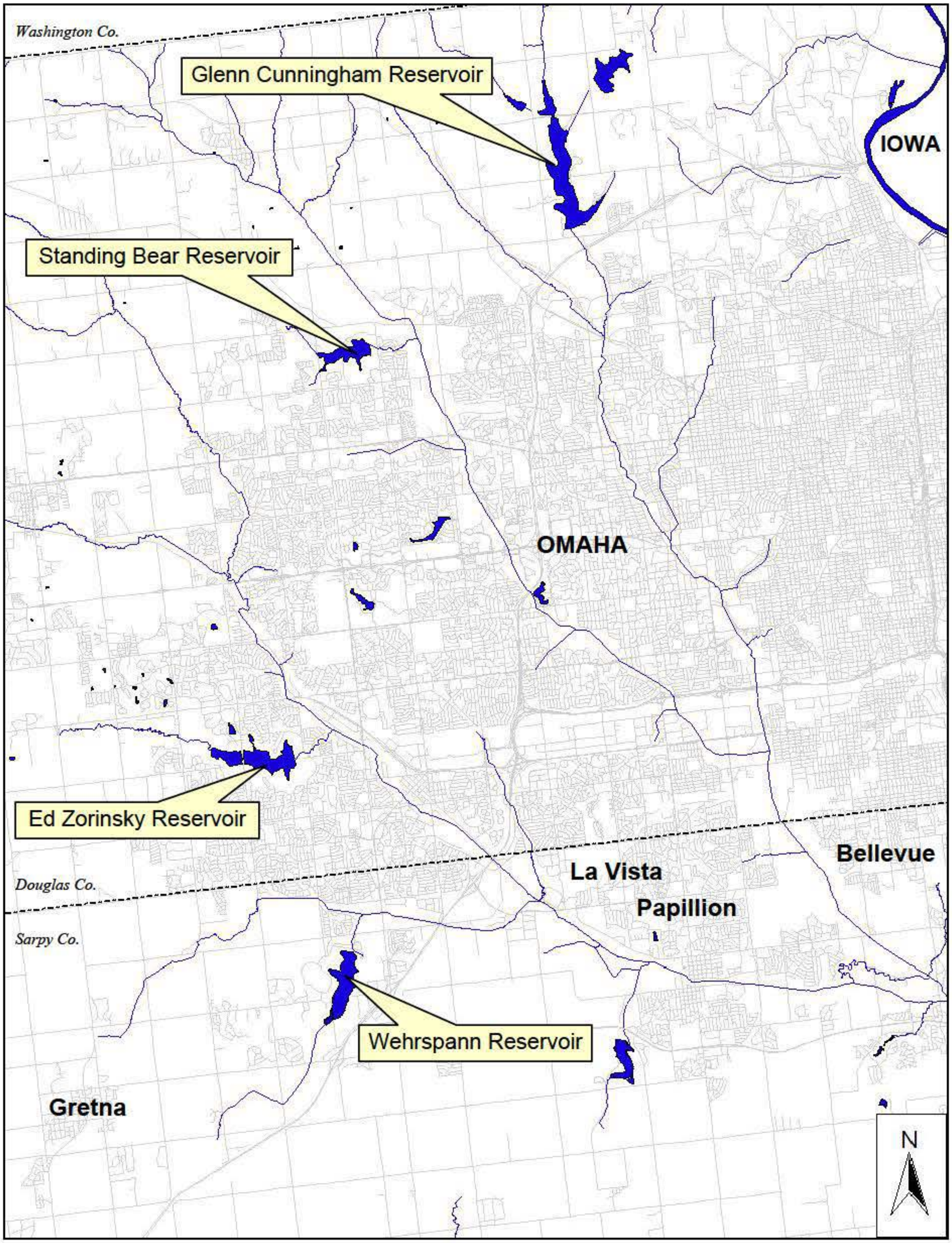

Figure 6.1. Location of the Corps' Papillion Creek Tributary reservoirs in the Omaha, Nebraska vicinity.

Table 6.1. Summary of selected engineering data for the Papillion Creek Tributary projects.

	Ed Zorinsky Reservoir (Dam Site No. 18)	**Glenn Cunningham Reservoir (Dam Site No. 11)**	**Standing Bear Reservoir (Dam Site No. 16)**	**Wehrspann Reservoir (Dam Site No. 20)**
General				
Dammed Stream	Boxelder Creek	Knight Creek	Trib Big Papillion Ck	Trib So Br Papillion Ck
Drainage Area	16 4 sq mi	17 8 sq mi	6 0 sq mi	13 1 sq mi
Reservoir Length[1]	1 5 miles	2 5 miles	1 0 miles	1 5 miles
Designated Water Quality Storage	620 ac-ft	820 ac-ft	0 ac-ft	490 ac-ft
Multipurpose Pool Elevation (Top)	1110 0 ft-msl	1121 0 ft-msl	1104 0 ft-msl	1095 8 ft-msl
Date of Dam Closure	7 Dec 1989[2]	5 Aug 1974	3 Oct 1972	21 Sep 1982
Date of Initial Fill[3]	22 Apr 1992	2 Sep 1977	24 Oct 1977	26 May 1987
"As-Built" Conditions[4]	(1985 Survey Data)	(1976 Survey Data)	(1976 Survey Data)	(1984 Survey Data)
Lowest Reservoir Bottom Elevation	1074 ft-msl	1090 ft-msl	1073 ft-msl	1060 ft-msl
Surface Area at top of Multipurpose Pool	259 ac	395 ac	135 ac	239 ac
Capacity of Multipurpose Pool	3,037 ac-ft	3,705 ac-ft	1,504 ac-ft	2,640 ac-ft
Mean Depth at top of Multipurpose Pool[5]	11 7 ft	9 4 ft	11 1 ft	11 0 ft
Latest Surveyed Conditions	(1997 Survey Data)	(1996 Survey Data)	(1998 Survey Data)	(1994 Survey Data)
Lowest Reservoir Bottom Elevation	1077 ft-msl	1100 ft-msl	1082 ft-msl	1065 ft-msl
Surface Area at top of Multipurpose Pool	259 ac	378 ac	123 ac	240ac
Capacity of Multipurpose Pool	2,916 ac-ft	3,054 ac-ft	1,211 ac-ft	2,529 ac-ft
Mean Depth at top of Multipurpose Pool[5]	11 3 ft	8 0 ft	9 9 ft	10 5 ft
Sediment Deposition in Multipurpose Pool				
Historic Sediment Deposition[6]	121 ac-ft	651 ac-ft	293 ac-ft	111 ac-ft
Annual Sedimentation Rate[7]	1990-1997 16 1 ac-ft/yr	1976-1996 31 0 ac-ft/yr	1976-1998 12 7 ac-ft/yr	1984-1994 10 6 ac-ft/yr
Current Estimated Sediment Deposition[8]	266 ac-ft	961 ac-ft	395 ac-ft	238 ac-ft
Current capacity of Multipurpose Pool[9]	2,771 ac-ft	2,744 ac-ft	1,109 ac-ft	2,402 ac-ft
Percent of "As-Built" Multipurpose Pool capacity lost to current estimated sediment deposition	9%	26%	26%	9%
Operational Details – Historic	(1992 – 2006)	(1978 – 2006)	(1978 – 2006)	(1987 – 2006)
Maximum Recorded Pool Elevation	1116 8 ft-msl 24-Jul-93	1125 3 ft-msl 7-Aug-99	1107 8 ft-msl 16-Jun-84	1103 2 ft-msl 24-Jul-93
Minimum Recorded Pool Elevation	1106 5 ft-msl 13-Aug-96	1100 9 ft-msl [10] 9-Jun-06	1096 0 ft-msl 28-Feb-91	1085 4 ft-msl 2-May-90
Maximum Recorded Daily Inflow	561 cfs 14-Jun-91	931 cfs 7-Aug-99	266 cfs 14-Jun-84	678 cfs 28-Jun-93
Maximum Recorded Daily Outflow	142 cfs 25-Jul-93	157 cfs 8-Aug-99	65 cfs 16-Jun-84	124 cfs 25-Jul-93
Average Annual Pool Elevation	1109 9 ft-msl	1120 9 ft-msl	1102 7 ft-msl	1093 0 ft-msl
Average Annual Inflow	4,269 ac-ft	7,320 ac-ft	1,296 ac-ft	2,075 ac-ft
Average Annual Outflow	3,547 ac-ft	6,247 ac-ft	855 ac-ft	1,105 ac-ft
Estimated Retention Time[11]	0 78 Years	0 44 Years	1 30 Years	2 17 Years
Operational Details – Current[12]				
Maximum Recorded Pool Elevation	1111 7 ft-msl 8-Aug-06	1121 0 ft-msl 11-Apr-06	1105 6 16-Aug-06	1093 0 25-Sep-06
Minimum Recorded Pool Elevation	1109 3 ft-msl 14-Nov-05	1100 9 ft-msl [10] 9-Jun-06	1102 6 18-Mar-06	1088 4 4-Aug-06
Maximum Recorded Daily Inflow	232 cfs 8-Aug-06	26 cfs 30-Mar-06	99 cfs 18-Aug-06	133 cfs 8-Aug-06
Maximum Recorded Daily Outflow	43 cfs 9-Aug-06	57 cfs 13-Apr-06	26 cfs 19-Aug-06	No Outflow
Total Inflow (% of Normal)	2,715 ac-ft (65%)	1,142 ac-ft (16%)	1,242 ac-ft (101%)	1,012 ac-ft (50%)
Total Outflow (% of Normal)	1,837 ac-ft (55%)	3,834 ac-ft (65%)	728 ac-ft (97%)	No Outflow
Outlet Works				
Ungated Outlets	2) 1 5'x3 5' 1110 0 ft-msl 2) 3 2'x8 0' 1117 6 ft-msl	2) 2 0'x4 0' 1121 0 ft-msl 2) 2 5'x9 0' 1127 5 ft-msl	2) 1 0'x2 5' 1104 0 ft-msl 2) 2 0'x6 0' 1109 0 ft-msl	2) 1 3'x3 5' 1095 8 ft-msl 2) 3 7'x8 0' 1103 4 ft-msl
Gated Outlets (Mid-depth)	1) 6" Dia 1104 3 ft-msl	None	None	1) 6" Dia 1090 0 ft-msl
Gated Outlets (Low-level)	1) 30"x30" 1090 0 ft-msl	1) 30"x30" 1100 0 ft-msl	1) 24"x36" 1080 0 ft-msl	1) 30"x30" 1077 0 ft-msl

(1) Reservoir length at top of conservation pool
(2) Dam completed 15-Jul-1984, low-level gate closed 7-Dec-1989
(3) First occurrence of reservoir pool elevation to top of multipurpose pool elevation
(4) "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
(5) Mean Depth = Volume ÷ Surface Area
(6) Difference in reservoir storage capacity to top of Multipurpose Pool between "as-built" and latest survey
(7) Annualized rate based on historic accumulated sediment
(8) Current accumulated sediment estimated from historic annual sedimentation rate
(9) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
(10) Reservoir drawn down for lake restoration project
(11) Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
(12) Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

6.1.1.2.2 Reservoir Regulation for Water Quality Management

6.1.1.2.2.1 Downstream Water Quality Management

When the Papillion Creek Tributary projects were authorized, water quality management was identified as a concern within the Papillion Creek basin. At that time, studies by the Federal Water Pollution Control Administration (FWPCA) indicated that a need existed for water quality storage within the basin. The FWPCA identified the need for 3 cfs water quality flow in the Big Papillion Creek, Little Papillion Creek, and West Branch Papillion Creek. The FWPCA's studies indicated 8 of the proposed 21 reservoirs would collectively have sufficient storage to provide the identified 3 cfs water quality flows. Based on the costs of an alternative groundwater pumping project at that time, this storage was estimated to have an annual value of $10,700. Dam sites 11 (i.e., Glenn Cunningham), 18 (i.e., Ed Zorinsky), and 20 (i.e., Wehrspann) were included in the eight reservoirs as having a water quality component in the multipurpose pool. Originally, Dam site 11 was to have a multipurpose pool of 4,600 ac-ft. Of this storage, 820 ac-ft was indicated as the water quality storage component. The 1976 survey of Glenn Cunningham Reservoir determined the multipurpose storage of the reservoir at that time was 3,705 ac-ft. Originally, Dam site 18 was to have a multipurpose pool of 4,700 ac-ft with a water quality component of 620 ac-ft. The 1984 survey of Ed Zorinsky Reservoir established the "as-built" multipurpose storage of the reservoir at 3,037 ac-ft. Originally, Dam site 20 was to have a multipurpose storage of 3,700 ac-ft with a water quality storage component 490 ac-ft. The 1984 survey of Wehrspann Reservoir determined the multipurpose storage of the reservoir at that time was 2,640 ac-ft. The multipurpose pools at the four Papillion Creek reservoirs were estimated to fill with sediment in 100 years. To date, releases for downstream water quality management have not been necessary because seepage, releases, and/or tributary inflows at Dam sites 11, 18, and 20 have provided adequate flow for water quality purposes.

6.1.1.2.2.2 Reservoir Water Quality Management

As stated above, seepage, ungated releases, and tributary inflows have been sufficient to provide the required downstream flows for water quality purposes. Since authorized water quality storage has not been required for downstream water quality purposes, it is available for upstream (reservoir) water quality management. The Papillion Creek tributary reservoirs are polymixic, and near-bottom areas of the reservoirs become anoxic during the summer and winter. Releases could be made from the reservoirs through the low-level outlet to discharge poor quality water during these times and replace it with better quality inflow water.

6.1.2 ED ZORINSKY RESERVOIR

6.1.2.1 <u>Background Information</u>

6.1.2.1.1 Project Overview

The dam forming Ed Zorinsky Reservoir is located on Boxelder Creek, a tributary of the South Papillion Creek in the West Branch Papillion Creek basin. The Ed Zorinsky Reservoir watershed is 16.4 square miles. The watershed was largely agricultural when the dam was built in 1984; however since then, the watershed has undergone extensive urbanization with the growth of Omaha.

The dam was completed on July 20, 1984; however, potential water quality problems delayed closure. Two wastewater treatment facilities occasionally discharged to upstream tributaries of the reservoir, and it was decided to delay final closure until the situation was addressed. The situation was corrected by constructing a diversion pipeline to the Elkhorn River in the fall of 1989. The low-level gate at the dam was closed on December 7, 1989 and the reservoir reached its initial fill in April 1992.

6.1.2.1.2 Ed Zorinsky Dam Intake Structure

The reinforced concrete intake structure at Ed Zorinsky Dam has four upper level intakes (two at invert elevation 1110.0 ft-msl and two at invert elevation 1117.6 ft-msl), an intermediate intake (invert elevation 1104.3 ft-msl) and a low-level intake (invert elevation 1090 ft-msl). The upper level intakes are uncontrolled. The intermediate intake has a 6-inch diameter slide gate for flow augmentation releases for water quality management. The low-level intake is provided with a slide gate to permit draining of the reservoir below elevation 1110.0 ft-msl, in the event drawdown is desirable. A low-level inlet is constructed 240 feet upstream of the intake tower. The inlet is provided with a trash rack and emergency bulkhead to allow closure with the gate open. A 30-inch R.C.P. (reinforced concrete pipe) connects the low-level inlet to the intake structure.

6.1.2.1.3 Reservoir Storage Zones

Figure 6.2 depicts the current storage zones of Ed Zorinsky Reservoir based on the 1997 survey data and estimated sedimentation. It is estimated that 9 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

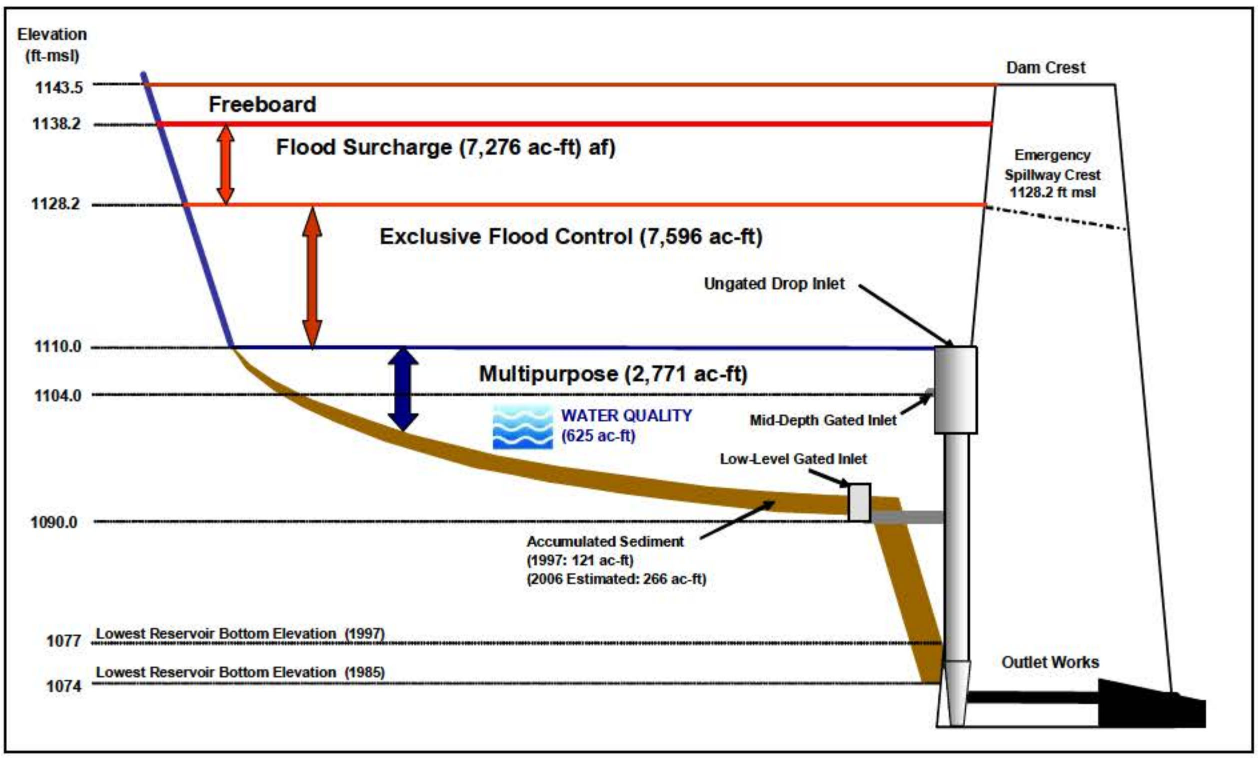

Figure 6.2. Current storage zones of Ed Zorinsky Reservoir based on the 1997 survey data and estimated sedimentation.

6.1.2.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Ed Zorinsky Reservoir since the reservoir was initially filled in the early 1990's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.3 shows the location of sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The near-dam location (i.e., EZRLKND1) was been continuously monitored since 1993.

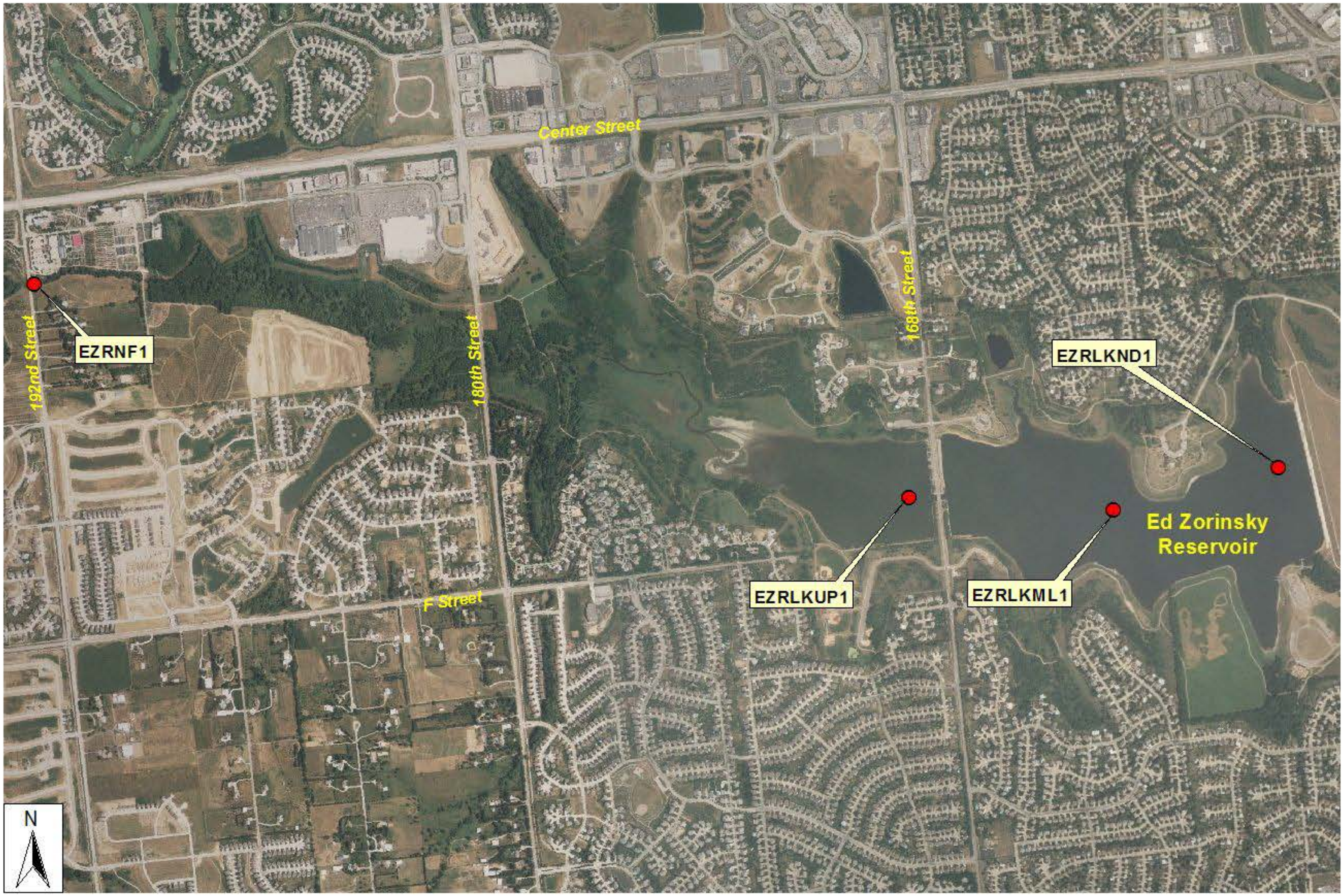

Figure 6.3. Location of sites where water quality monitoring was conducted by the District at Ed Zorinsky Reservoir during the period 2002 through 2006.

6.1.2.2 Water Quality in Ed Zorinsky Reservoir

6.1.2.2.1 Existing Water Quality Conditions (2002 through 2006)

6.1.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Ed Zorinsky Reservoir at sites EZRLKND1, EZRLKML1, and EZRLKUP1 from May through September during the 5-year period 2002 through 2006 are summarized in Plates 1 through 3. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, total ammonia, and nutrients.

A significant number of dissolved oxygen measurements throughout Ed Zorinsky Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 1-3). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and appeared to be associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Ed Zorinsky Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

A few pH readings throughout Ed Zorinsky Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life; however, the number of pH criterion exceedences was less than 10 percent and are not believed to be a significant concern at this time (Plates 1-3). It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Ed Zorinsky Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred. Also, the higher ammonia values were generally associated with near-bottom samples and the numeric ammonia criteria may not be applicable if thermal stratification was present. The higher ammonia levels may be associated with the reduction of nitrates as dissolved oxygen is degraded in the hypolimnion during thermal stratification.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were exceeded throughout the reservoir (Plates 1-3). The chlorophyll *a* criterion was exceeded by over 40% of the samples taken in the downstream and upstream areas of the reservoir. The total phosphorus and total nitrogen criteria were exceeded by over 10% of the samples.

6.1.2.2.1.2 Summer Thermal Stratification

6.1.2.2.1.2.1 2006 Longitudinal Temperature Contour Plots

Summer thermal stratification of Ed Zorinsky Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites EZRLKND1, EZRLKML1, and EZRLKUP1 (Plate 4). The contour plots were constructed along the length of the reservoir. Plate 4 indicates that significant thermal stratification was

present in Ed Zorinsky Reservoir during late-spring to mid-summer 2006. A 6° to 8°C difference between surface and bottom water temperature was present. By late-summer the thermal stratification had dissipated (Plate 4).

6.1.2.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Ed Zorinsky Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 5). The plotted depth-profile temperature measurements indicate that the reservoir periodically exhibits significant thermal stratification (Plate 5). Based on the periodic occurrence of thermal stratification in the summer, Ed Zorinsky Reservoir appears to be polymixic.

6.1.2.2.1.3 Summer Dissolved Oxygen Conditions

6.1.2.2.1.3.1 2006 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Ed Zorinsky Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites EZRLKND1, EXRLKML1, and EZRLKUP1 (Plate 6). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored near the reservoir bottom during all 3 months. However, the anoxic area was much larger during the month of July (Plate 6). Summer thermal stratification of Ed Zorinsky Reservoir in 2006 apparently was prolonged enough to allow an extensive area of degraded dissolved oxygen to occur. An ORP (oxidation-reduction potential) reading of -37 mV was measured in August 2006 near the bottom in the deepest area of the reservoir.

6.1.2.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Ed Zorinsky Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 7). On most occasions, there was a significant vertical gradient in summer dissolved oxygen levels in Ed Zorinsky Reservoir, with the vertical dissolved oxygen profiles exhibiting a clinograde distribution. However, there were times, typically in late summer, when dissolved oxygen levels were above 5 mg/l from the reservoir surface to the bottom (Plate 7). As was noted in discussing the temperature depth-profile plots, Ed Zorinsky Reservoir seems to be polymixic, and during periods of prolonged stratification anoxic conditions readily develop near the reservoir bottom.

6.1.2.2.1.4 Water Clarity

6.1.2.2.1.4.1 Secchi Transparency

Figure 6.4 displays a box plot of the Secchi depth transparencies measured at the three in-reservoir monitoring sites (i.e., EZRLKND1, EZRLKML1, and EZRLKUP1) during the 5-year period 2002 through 2006 (note: the three monitoring sites are oriented in an upstream to downstream direction). Secchi depth transparency at site EZRLKUP1 was significantly lower than the Secchi depth transparencies at sites EZRLKML1 and EZRLKND1 (i.e., nonoverlapping inter-quartile ranges). Secchi depths measured at sites EZRML1 and EZRLKND1 were similar (Figure 6.4). The 168th street Bridge separates Ed Zorinsky Reservoir into an upper and a lower basin (Figure 6.3). The upper basin acts as a "wet" sedimentation basin for the lower basin. Site EZRLKUP1 is in the upper basin, while sites EZRLKML1 and EZRLKND1 are in the lower basin.

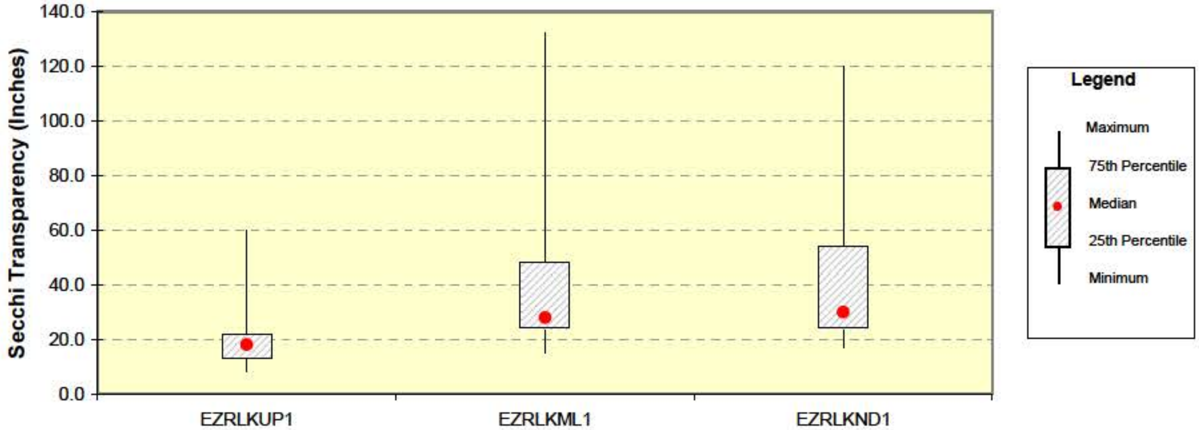

Figure 6.4. Box plot of Secchi depth transparencies measured in Ed Zorinsky Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.)

6.1.2.2.1.4.2 <u>Turbidity</u>

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Ed Zorinsky Reservoir from the depth-profile turbidity measurements taken at sites EZRLKND1, EZRLKML1, and EZRLKUP1 during 2006 (Plate 8). As seen in Plate 8, turbidity levels in Ed Zorinsky Reservoir vary longitudinally from the dam to reservoir's upper reaches. As expected, turbidity levels are higher in the upper reaches of the reservoir.

6.1.2.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Ed Zorinsky Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site EZRLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 9). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Two parameters, dissolved oxygen and total ammonia, varied significantly between the surface and bottom (Plate 9). Near-bottom levels of dissolved oxygen and total ammonia were, respectively, significantly lower and higher than near-surface levels. Measured near-bottom oxidation-reduction potential levels declined steadily through the summer months, and approached zero in late summer (Plate 9).

6.1.2.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Ed Zorinsky Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., EZRLKND1). Table 6.2 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Ed Zorinsky Reservoir is in a eutrophic condition.

Table 6.2. Summary of Trophic State Index (TSI) values calculated for Ed Zorinsky Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	61	64	44	72
TSI(TP)	25	58	57	48	73
TSI(Chl)	22	67	64	50	85
TSI(Avg1)	25	61	61	49	73
TSI(Avg2)	22	62	63	52	73

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.1.2.2.2 Water Quality Trends (1980 through 2006)

Ed Zorinsky Reservoir reached initial fill in 1992 and water quality monitoring of the reservoir began in 1993. Water quality trends from 1993 to 2006 were determined for Ed Zorinsky Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., EZRLKND1). Plate 10 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Ed Zorinsky Reservoir exhibited decreasing transparency and increasing levels of chlorophyll *a* (Plate 10). No trend in total phosphorus concentrations is observable (Plate 10). Over the 14-year period since 1993, Ed Zorinsky Reservoir has generally remained in a moderately eutrophic to eutrophic condition. However, if the current trend continues, the reservoir appears to be moving towards a hypereutrophic condition (Plate 10).

6.1.2.3 <u>Existing Water Quality Conditions of Runoff Inflows to Ed Zorinsky Reservoir</u>

Existing water quality in Box Elder Creek, above Ed Zorinsky Reservoir, was monitored under runoff conditions during the period of April through September at site EZRNF1. The site is approximately 1½ miles upstream from the reservoir (Figure 6.3). Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 11 summarizes water quality conditions that were monitored at site EZRNF1 under runoff conditions during the period 2002 through 2006.

6.1.3 GLENN CUNNINGHAM RESERVOIR

6.1.3.1 <u>Background Information</u>

6.1.3.1.1 Project Overview

The dam forming Glenn Cunningham Reservoir is located on Knight Creek, a tributary to Little Papillion Creek. The dam was completed on August 5, 1974 and the reservoir reached its initial fill on September 2, 1977. The Glenn Cunningham Reservoir watershed is 17.8 square miles. The watershed has remained largely agricultural since the dam was built in 1974; however, widespread acreage development is presently occurring.

6.1.3.1.2 Aquatic Habitat Restoration Project

An aquatic habitat restoration project was initiated at Glenn Cunningham Reservoir in 2006. To facilitate implementation of the project, the reservoir was drained in the spring of 2006. The project consists of two phases: 1) construction of in-reservoir habitat structures and modification of the outlet structure, and 2) rehabilitation and creation of wetland habitat in the reservoir and floodplain immediately upstream of the Nebraska Hwy 36 Bridge. The project is scheduled for completion in December 2008.

6.1.3.1.3 Reservoir Storage Zones

Figure 6.5 depicts the storage zones of Glenn Cunningham Reservoir based on the 1996 survey data and estimated sedimentation. These storage zones are the conditions that existed prior to the implementation of the ongoing aquatic habitat restoration project. The implementation of the aquatic habitat project may cause the storage zones of the reservoir to change as accumulated sediment is removed and redistributed. The dam intake structure is also being modified as part of the ongoing aquatic habitat restoration project. It is estimated that 27 percent of the Multipurpose Pool had been lost to sedimentation as of 2005 when the aquatic habitat lake restoration project was implemented.

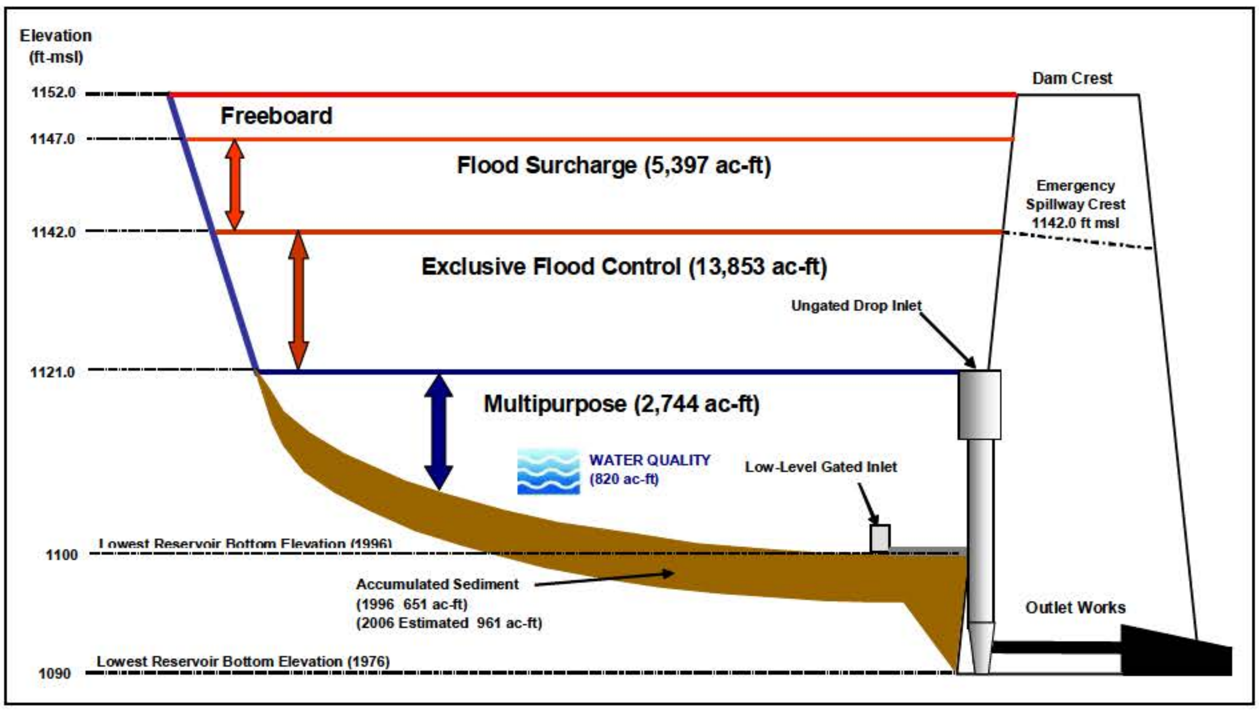

Figure 6.5. Current storage zones of Glenn Cunningham Reservoir based on the 1997 survey data and estimated sedimentation (prior to the ongoing aquatic habitat restoration project).

6.1.3.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Glenn Cunningham Reservoir since the reservoir was initially filled in the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.6 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). Because the reservoir was drawn down in 2006 for aquatic habitat restoration, water quality monitoring during 2006 only occurred at the inflow sites (i.e., GCRNFNRTH1 AND GCRNFEAST1). The near-dam location (GCRLKND1) was continuously monitored from 1980 to 2005.

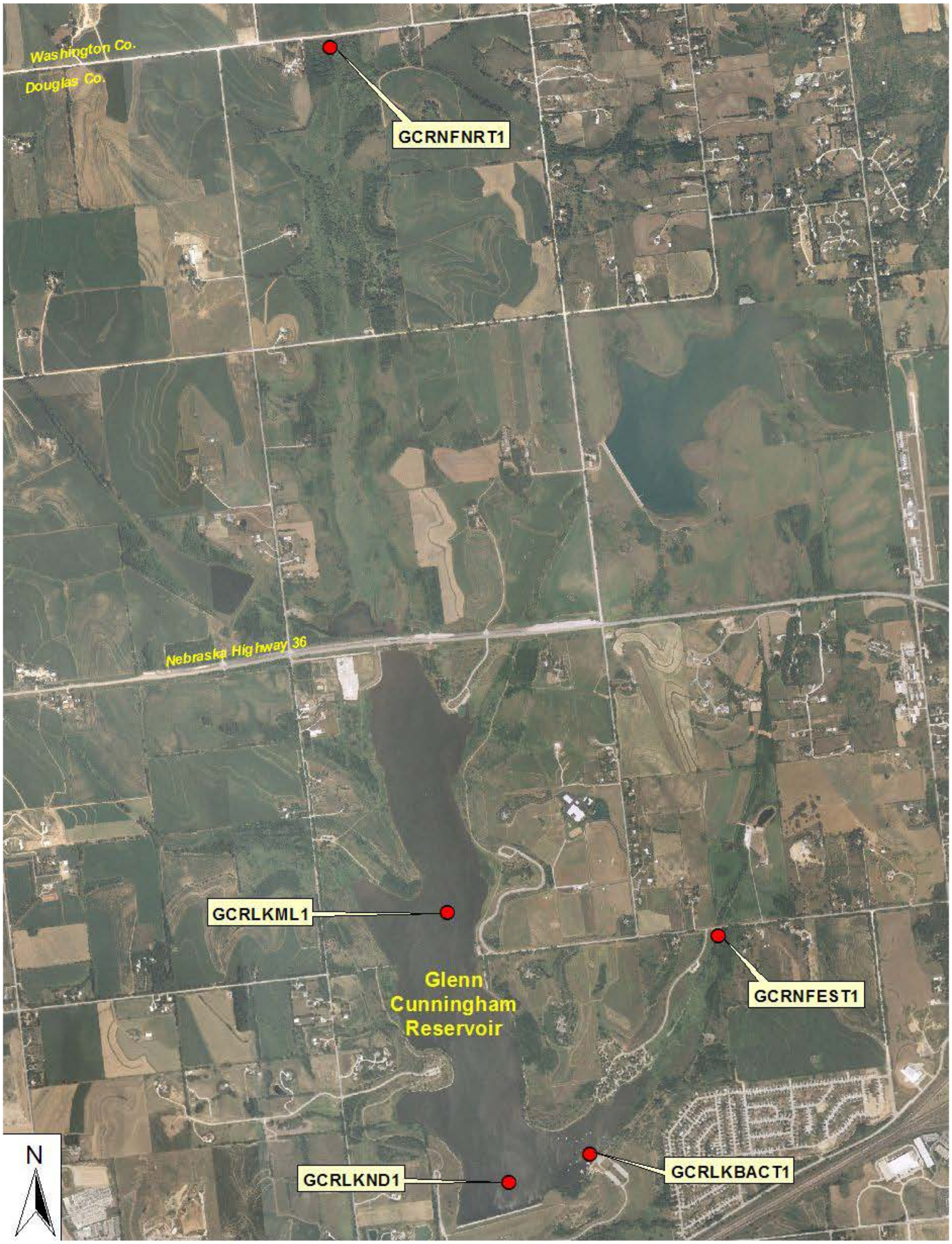

Figure 6.6. Location of sites where water quality monitoring was conducted by the District at Glenn Cunningham Reservoir during the period 2002 through 2006.

6.1.3.2 <u>Water Quality in Glenn Cunningham Reservoir</u>

6.1.3.2.1 Existing Water Quality Conditions (2002 through 2005)

6.1.3.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Glenn Cunningham Reservoir at sites GCRLKND1 and GCRLKML1 from May through September during the 4-year period 2002 through 2005 are summarized, respectively, in Plate 12 and 13. Water quality monitoring was not conducted at the sites in 2006 due to the reservoir being drawn down. A review of the results indicated possible water quality concerns regarding dissolved oxygen, pH, and nutrients.

A significant number of dissolved oxygen measurements throughout Glenn Cunningham Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 12 and 13). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and appeared to be associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Glenn Cunningham Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

A few pH readings in Glenn Cunningham Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life; however, the number of pH criterion exceedences was less than 10 percent and are not believed to be a significant concern at this time (Plates 12 and 13). It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

Nutrient criteria defined in Nebraska's water quality standards for R14 impounded waters include: total phosphorus (134 ug/l), total nitrogen (1,460 ug/l), and chlorophyll *a* (44 ug/l). All three of these criteria were exceeded in the reservoir (Plates 12 and 13). The chlorophyll *a* criterion was exceeded by 25% to over 50% of the samples taken in the lower area of the reservoir. The total phosphorus and total nitrogen criteria were exceeded by over 30% of the samples.

6.1.3.2.1.2 Summer Thermal Stratification and Dissolved Oxygen Conditions

6.1.3.2.1.2.1 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Glenn Cunningham Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 14). The plotted depth-profile temperature measurements indicate that the reservoir periodically exhibits some thermal stratification (Plate 14). Based on the periodic occurrence of thermal stratification in the summer, Glenn Cunningham Reservoir appears to be polymixic.

6.1.3.2.1.2.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Glenn Cunningham Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5

years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 15). On several occasions, there was a significant vertical gradient in summer dissolved oxygen levels in Glenn Cunningham Reservoir, with the vertical dissolved oxygen profiles exhibiting a clinograde distribution. However, there were times when dissolved oxygen levels were above 5 mg/l from the reservoir surface to the bottom (Plate 15). As was noted in discussing the temperature depth-profile plots, Glen Cunningham Reservoir seems to be polymixic, and during periods of prolonged stratification anoxic conditions readily develop near the reservoir bottom.

6.1.3.2.1.3 Water Clarity

Figure 6.7 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., GCRLKND1 and GCRLKML1) during the 4-year period 2002 through 2005 (note: the two monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies at sites GCRLKML1 and GCRLKND1 were similar with the mid-lake site, overall, being a little lower.

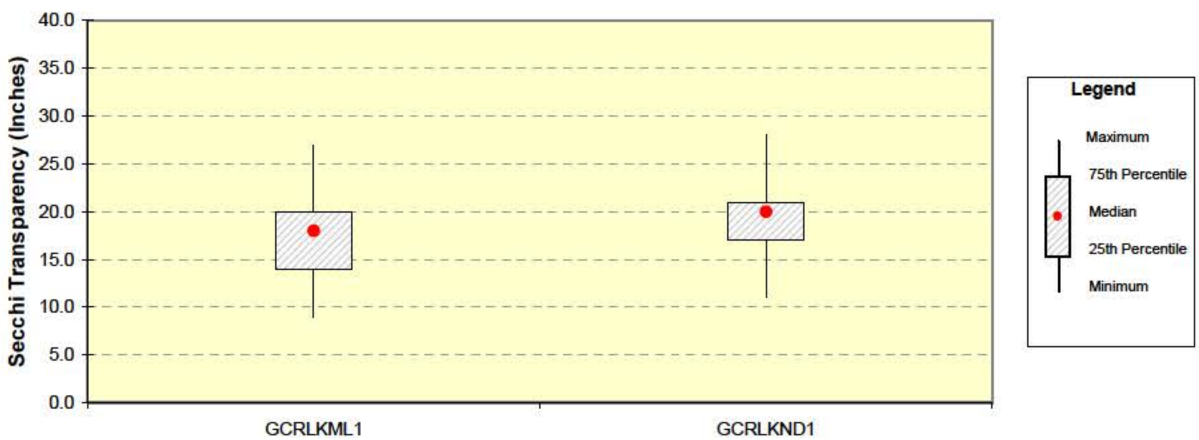

Figure 6.7 Box plot of Secchi depth transparencies measured in Glenn Cunningham Reservoir during the period 2002 through 2005. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.1.3.2.1.4 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Glenn Cunningham Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site GCRLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 16). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Although no parameters varied significantly between the surface and bottom, dissolved oxygen and total ammonia exhibited an appreciable level of difference between the surface and bottom (Plate 16).

6.1.3.2.1.5 Reservoir Trophic Status

Trophic State Index (TSI) values for Glenn Cunningham Reservoir were calculated from monitoring data collected during the 4-year period 2002 through 2005 at the near-dam ambient

monitoring site (i.e., GCRLKND1). Table 6.3 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Glenn Cunningham Reservoir was in a hypereutrophic condition.

Table 6.3. Summary of Trophic State Index (TSI) values calculated for Glenn Cunningham Reservoir for the 4-year period 2002 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	20	71	70	63	78
TSI(TP)	21	65	64	59	82
TSI(Chl)	19	55	72	72	82
TSI(Avg1)	21	69	69	60	77
TSI(Avg2)	17	69	69	60	74

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.1.3.2.1.6 Bacteria Monitoring

A designated swimming beach is not located on Glenn Cunningham Reservoir; however, the reservoir is used extensively for sailing and wind surfing. Since these recreational uses can lead to direct contact with water, bacteria monitoring was conducted at the reservoir. During the 4-year period 2002 through 2005, bacteria samples were collected weekly from May through September near the marina boat ramp on Glenn Cunningham Reservoir (i.e., site GCRLKBACT1) (Figure 6.6). Table 6.4 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of “full-body contact” recreation:

<u>Fecal Coliform:</u>
Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

<u>*E. coli*</u>:
E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, “full-body contact” recreation was fully supported, but threatened, in Glenn Cunningham Reservoir during the May through September recreational season. The geomean criteria for fecal coliform and *E. coli* were, respectively, exceeded by 3% and 4% of the calculated geomeans during the 4-year period 2002 through 2005. The higher bacteria levels monitored in the reservoir are believed to be associated with runoff situations.

Table 6.4. Summary of weekly (May through September) bacteria samples collected at Glenn Cunningham Reservoir (i.e., site GCRLKBACT1) during the 4-year period 2002 through 2005.

Fecal Coliform Bacteria – Individual Samples		***E. coli* – Individual Samples**	
Number of Samples	83	Number of Samples	81
Mean (cfu/100ml)	81	Mean (cfu/100ml)	57
Median (cfu/100ml)	20	Median (cfu/100ml)	20
Minimum (cfu/100ml)	n.d.	Minimum (cfu/100ml)	n.d.
Maximum (cfu/100ml)	1,110	Maximum (cfu/100ml)	610
Percent of samples exceeding 400/100ml	6%	Percent of samples exceeding 235/100ml	6%
Fecal Coliform Bacteria – Geomeans		***E. coli* – Geomeans**	
Number of Geomeans	68	Number of Geomeans	68
Average	40	Average	28
Median	20	Median	14
Minimum	2	Minimum	2
Maximum	393	Maximum	289
Number of Geomeans exceeding 200/100ml	3%	Number of Geomeans exceeding 126/100ml	4%

n.d. = nondetected.
Note: Nondetected values set to 1 to calculate mean and geomean.

6.1.3.2.2 Water Quality Trends (1980 through 2005)

Water quality trends from 1980 to 2005 were determined for Glenn Cunningham Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., GCRLKND1). Plate 17 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Glenn Cunningham Reservoir exhibited decreasing transparency and increasing levels of total phosphorus (Plate 17). No trend in chlorophyll *a* levels is observable (Plate 17). Over the 26-year period since 1980, Glenn Cunningham Reservoir had moved from a eutrophic to a hypereutrophic condition (Plate 17).

6.1.3.3 Existing Water Quality Conditions of Runoff Inflows to Glenn Cunningham Reservoir

Existing water quality in the north and east inflows to Glenn Cunningham Reservoir were monitored under runoff conditions, during the period of April through September, respectively at sites GCRNFNRT1 and GCRNFEST1. Site GCRNFNRT1 is 2 miles upstream from the reservoir, and site GCRNFEST1 is approximately ½ mile upstream of the reservoir (Figure 6.6). Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from “base-flow” conditions. Plates 18 and 19, respectively, summarize water quality conditions that were monitored at sites GCRNFNRT1 and GCRNFEST1 under runoff conditions during the period 2002 through 2006. Levels of atrazine in the Knight Creek inflow to Glen Cunningham Reservoir may be a concern as 4 of 15 (27%) collected samples exceeded the chronic criteria of 12 ug/l for the protection of aquatic life. All of the criteria exceedences occurred during spring runoff (i.e., April and May).

6.1.4 STANDING BEAR RESERVOIR

6.1.4.1 Background Information

6.1.4.1.1 Project Overview

The dam forming Standing Bear Reservoir is located on an unnamed tributary of Big Papillion Creek. The Standing Bear Reservoir watershed is 6.0 square miles. The watershed was largely agricultural when the dam was built in 1972; however since then, the watershed has undergone extensive urbanization with the growth of Omaha. The reservoir reached its initial fill in October 1977.

6.1.4.1.2 Standing Bear Dam Intake Structure

The reinforced concrete intake structure at Standing Bear dam has uncontrolled openings at two levels in addition to a low-level gate. Uncontrolled flood control weirs are at elevation 1109 ft-msl and smaller openings for the conservation pool are at elevation 1104 ft-msl. The inlet to the low-level gate is located 302 feet upstream of the intake structure at elevation 1080 ft-msl. The ungated openings and the low-level inlet are protected with metal trash racks.

6.1.4.1.3 Reservoir Storage Zones

Figure 6.8 depicts the current storage zones of Standing Bear Reservoir based on the 1998 survey data and estimated sedimentation. It is estimated that 27 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

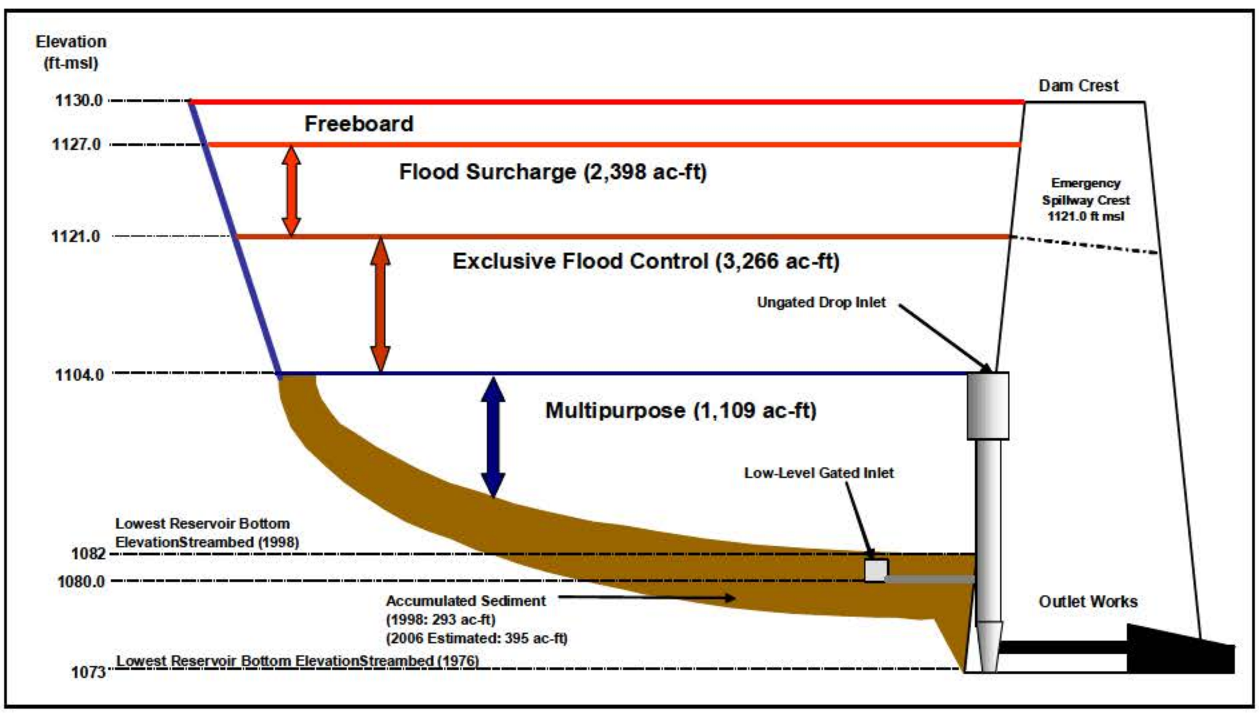

Figure 6.8. Current storage zones of Standing Bear Reservoir based on the 1998 survey data and estimated sedimentation.

6.1.4.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Standing Bear Reservoir since the reservoir was initially filled in the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.9 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The near-dam location (STBLKND1) has been continuously monitored since 1980.

6.1.4.2 Water Quality in Standing Bear Reservoir

6.1.4.2.1 Existing Water Quality Conditions (2002 through 2006)

6.1.4.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Standing Bear Reservoir at sites STBLKND1 and STBLKML1 from May through September during the 5-year period 2002 through 2006 are summarized, respectively, in Plates 20 and 21. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, total ammonia, and nutrients.

A significant number of dissolved oxygen measurements throughout Standing Bear Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 20 and 21). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and appeared to be associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Standing Bear Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

A few pH readings throughout Standing Bear Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life; however, the number of pH criterion exceedences was less than 10 percent and are not believed to be a significant concern at this time (Plates 20 and 21). It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Standing Bear Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred. Also, the one exceedence of the criterion was measured in a near-bottom sample, and the numeric ammonia criteria may not be applicable if thermal stratification was present. The higher near-bottom ammonia conditions may be associated with the reduction of nitrates as dissolved oxygen is degraded in the hypolimnion during thermal stratification.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were exceeded throughout the reservoir (Plates 20 and 21). The chlorophyll *a* criterion was exceeded most often, with the total phosphorus and total nitrogen criteria being exceeded to a lesser extent (Plate 20).

Figure 6.9. Location of sites where water quality monitoring was conducted by the District at Standing Bear Reservoir during the period 2002 through 2006.

6.1.4.2.1.2 Summer Thermal Stratification

6.1.4.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Standing Bear Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites STBLKND1 and STBLKML1 (Plate 22). The contour plots were constructed along the length of the reservoir. Plate 22 indicates that significant thermal stratification was present in Standing Bear Reservoir during late-spring to mid-summer 2006. A 6° to 8°C difference between surface and bottom water temperature was present. By late-summer the thermal stratification had dissipated (Plate 22).

6.1.4.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Standing Bear Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 23). The plotted depth-profile temperature measurements indicate that the reservoir periodically exhibits significant thermal stratification (Plate 23). Based on the periodic occurrence of thermal stratification in the summer, Standing Bear Reservoir appears to be polymixic.

6.1.4.2.1.3 Summer Dissolved Oxygen Conditions

6.1.4.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Standing Bear Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites STBLKND1 and STBLKML1 (Plate 24). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored near the reservoir bottom during all 3 months. However, the anoxic area was much larger during the month of July (Plate 24). Summer thermal stratification of Standing Bear Reservoir in 2006 apparently was prolonged enough to allow an extensive area of degraded dissolved oxygen to occur. An ORP (oxidation-reduction potential) reading of -21 mV was measured in August 2006 near the bottom of the reservoir near the dam.

6.1.4.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Standing Bear Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 25). On most occasions, there was a significant vertical gradient in summer dissolved oxygen levels in Standing Bear Reservoir, with the vertical dissolved oxygen profiles exhibiting a clinograde distribution. All of the summer dissolved oxygen depth profiles measured over the 5-year period had near-bottom dissolved oxygen concentrations less than 5 mg/l (Plate 25). As was noted in discussing the temperature depth-profile plots, Standing Bear Reservoir seems to be polymixic, and during the summer anoxic conditions readily develop near the reservoir bottom.

6.1.4.2.1.4 Water Clarity

6.1.4.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.10 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., STBLKND1 and STBLKML1) during the 5-year period 2002 through 2006 (note: the two monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies at sites STBLKML1 and STBLKND1 were similar.

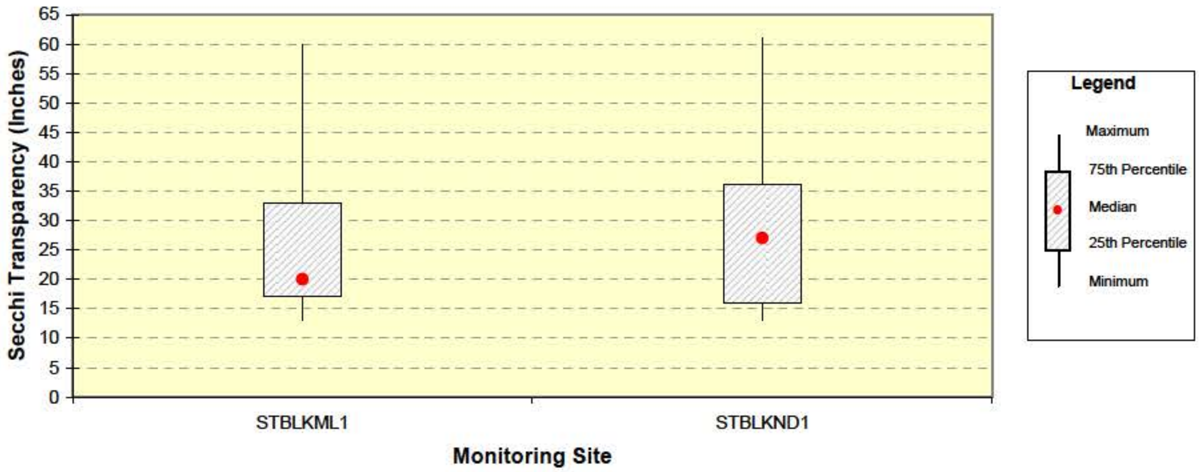

Figure 6.10. Box plot of Secchi depth transparencies measured in Standing Bear Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.1.4.2.1.4.2 <u>Turbidity</u>

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Standing Bear Reservoir from the depth-profile turbidity measurements taken at sites STBLKND1 and STBLKML1 during 2006 (Plate 26). As seen in Plate 26, Standing Bear Reservoir did not exhibit a lot of longitudinal variability in turbidity.

6.1.4.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Standing Bear Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site STBLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 27). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen, varied significantly between the surface and bottom (Plate 27). Near-bottom levels of dissolved oxygen were significantly lower than near-surface levels. Measured near-surface and near-bottom concentrations of total ammonia were nearly significantly different, with the near-bottom concentrations being higher (Plate 27). Measured near-bottom oxidation-reduction potential levels declined steadily through the summer months, and typically reached negative values in late summer (Plate 27).

6.1.4.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Standing Bear Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., STBLKND1). Table 6.5 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Standing Bear Reservoir is in a eutrophic condition.

Table 6.5. Summary of Trophic State Index (TSI) values calculated for Standing Bear Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	66	65	54	76
TSI(TP)	25	58	57	48	74
TSI(Chl)	21	68	69	55	81
TSI(Avg1)	25	64	63	53	76
TSI(Avg2)	21	64	63	53	76

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.1.4.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Standing Bear Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., STBLKND1). Plate 28 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Standing Bear Reservoir exhibited slightly decreasing transparency (Plate 28). No trends in total phosphorus or chlorophyll *a* levels are observable (Plate 28). Over the 27-year period since 1980, Standing Bear Reservoir has remained in a eutrophic condition (Plate 28).

6.1.4.3 <u>Existing Water Quality Conditions of Runoff Inflows to Standing Bear Reservoir</u>

Existing water quality in the north and south inflows to Standing Bear Reservoir were monitored under runoff conditions, during the period of April through September, respectively at sites STBNFNRT1 and STBNFSTH1. Both sites are approximately ¼ mile upstream of the reservoir (Figure 6.9). Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plates 29 and 30, respectively, summarize water quality conditions that were monitored at sites STBNFNRT1 and STBNFSTH1 under runoff conditions during the period 2002 through 2006.

6.1.5 WEHRSPANN RESERVOIR

6.1.5.1 Background Information

6.1.5.1.1 Project Overview

The dam forming Wehrspann Reservoir is located on a tributary to the South Branch Papillion Creek. The dam was completed on September 21, 1982 and the reservoir reached its initial fill on May 26, 1987. The Wehrspann Reservoir watershed is 13.1 square miles. The watershed was largely agricultural when the dam was built in 1982. Recently however, the watershed has undergone increased urbanization with the growth of Gretna and acreage development.

6.1.5.1.2 Aquatic Habitat Improvement and Water Quality Management Project

A Section 1135 aquatic habitat improvement and water quality management project was completed at Wehrspann Reservoir in 1999. The project consisted of a sediment control structure, sediment detention pond/wetlands, and tree and shrub mitigation plantings. The sediment control structure dam was located approximately ½ mile upstream of the reservoir (see Figure 6.12). A detention area was formed upstream of the sediment dam to capture and store sediments that would enter Wehrspann Reservoir. The natural detention area was further excavated and graded to maximize retention volume and wetlands creation. The sediment storage area will ultimately become a wet meadow-scrub wetland-grassland mosaic, unless sediment that collects is periodically removed. The detention area was designed to ultimately fill with sediment to the top of the spillway crest elevation of 1117 ft-msl. The detention area has a design capacity of 469 ac-ft with a maximum surface area of approximately 76 acres. A nonpoint source water quality management project to educate landowners and implement best management practices (BMPs) was also implemented in the watershed when the Section 1135 project was constructed.

6.1.5.1.3 Wehrspann Dam Intake Structure

The reinforced concrete intake structure has two upper level intakes (invert elevations 1096.0 and 1103.4 ft-msl), an intermediate intake (invert elevation 1090.0 ft-msl), and also a low-level intake (invert elevation 1074.0 ft-msl). The upper level intakes are uncontrolled. The low-level intake is provided with a slide gate to allow draining of the reservoir. The intermediate intake is a 6-inch diameter slide gate for flow augmentation releases. A low-level inlet is constructed 130 feet upstream of the intake tower. The inlet is provided with a trash rack and emergency bulkhead to allow closure with the gate open. A 30-inch R.C.P. connects the low-level inlet to the intake structure.

6.1.5.1.4 Reservoir Storage Zones

Figure 6.11 depicts the current storage zones of Wehrspann Reservoir based on the 1994 survey data and estimated sedimentation. It is estimated that 9 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

6.1.5.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Wehrspann Reservoir since the reservoir was initially filled in the late 1980's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.12 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The near-dam location (WEHLKND1) has been continuously monitored since 1986.

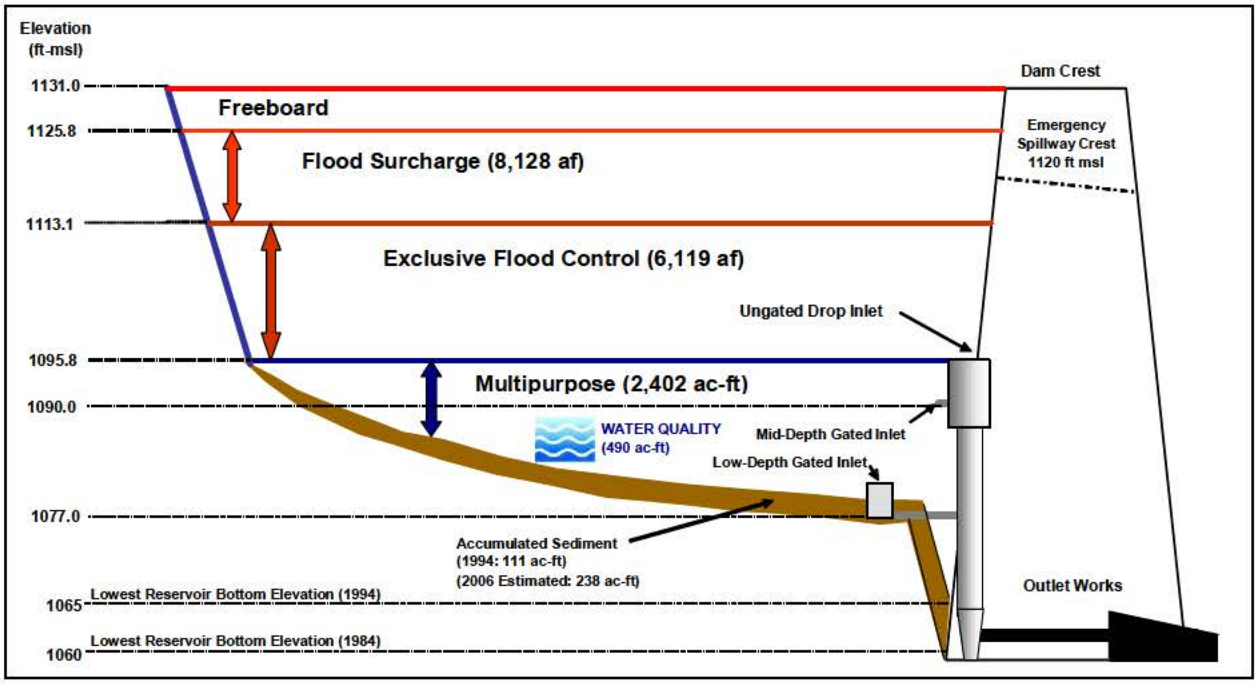

Figure 6.11. Current storage zones of Wehrspann Reservoir based on the 1994 survey data and estimated sedimentation.

6.1.5.2 <u>Water Quality in Wehrspann Reservoir</u>

6.1.5.2.1 Existing Water Quality Conditions (2002 through 2006)

6.1.5.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Wehrspann Reservoir at sites WEHLKND1 and WEHLKML1 from May through September during the 5-year period 2002 through 2006 are summarized, respectively, in Plates 31 and 32. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, total ammonia, and nutrients.

A significant number of dissolved oxygen measurements throughout Wehrspann Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 31 and 32). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and appeared to be associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Wehrspann Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

A few pH readings throughout Wehrspann Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life; however, the number of pH criterion exceedences was less than 10 percent and are not believed to be a significant concern at this time (Plates 31 and 32). It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

Figure 6.12. Location of sites where water quality monitoring was conducted by the District at Wehrspann Reservoir during the period 2002 through 2006.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Wehrspann Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred. Also, the three values exceeding the criterion were measured in near-bottom samples, and the numeric ammonia criteria may not be applicable if thermal stratification was present. The higher near-bottom ammonia conditions may be associated with the reduction of nitrates as dissolved oxygen is degraded in the hypolimnion during thermal stratification.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). The total nitrogen criterion was not exceeded, while the total phosphorus and chlorophyll *a* criteria were regularly exceeded throughout the reservoir (Plates 31 and 32).

6.1.5.2.1.2 Summer Thermal Stratification

6.1.5.2.1.2.1 2006 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Wehrspann Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites WEHLKND1 and WEHLKML1 (Plate 33). The contour plots were constructed along the length of the reservoir. Plate 33 indicates that appreciable thermal stratification was not monitored in Wehrspann Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 2° to 3°C (Plate 33).

6.1.5.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Wehrspann Reservoir, at the deepwater area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 34). The plotted depth-profile temperature measurements indicate that the reservoir occasionally exhibits some thermal stratification (Plate 34). Based on the occasional occurrence of thermal stratification in the summer, Wehrspann Reservoir appears to be polymixic.

6.1.5.2.1.3 Summer Dissolved Oxygen Conditions

6.1.5.2.1.3.1 2006 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Wehrspann Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites WEHLKND1 and WEHLKML1 (Plate 35). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored near the reservoir bottom during July. Summer thermal stratification of Wehrspann Reservoir in 2006 apparently was significant enough to allow degraded dissolved oxygen to occur near the reservoir bottom. An ORP (oxidation-reduction potential) reading of 117 mV was measured in July 2006 near the bottom of the reservoir near the dam.

6.1.5.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Wehrspann Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 36). There was a significant vertical gradient in summer dissolved oxygen levels in over half of the measured depth

profiles. As was noted in discussing the temperature depth-profile plots, Wehrspann Reservoir seems to be polymixic, and during the summer degraded dissolved oxygen readily develop near the reservoir bottom.

6.1.5.2.1.4 Water Clarity

6.1.5.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.13 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., WEHLKND1 and WEHLKML1) during the 5-year period 2002 through 2006 (note: the two monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies at the two sites were similar.

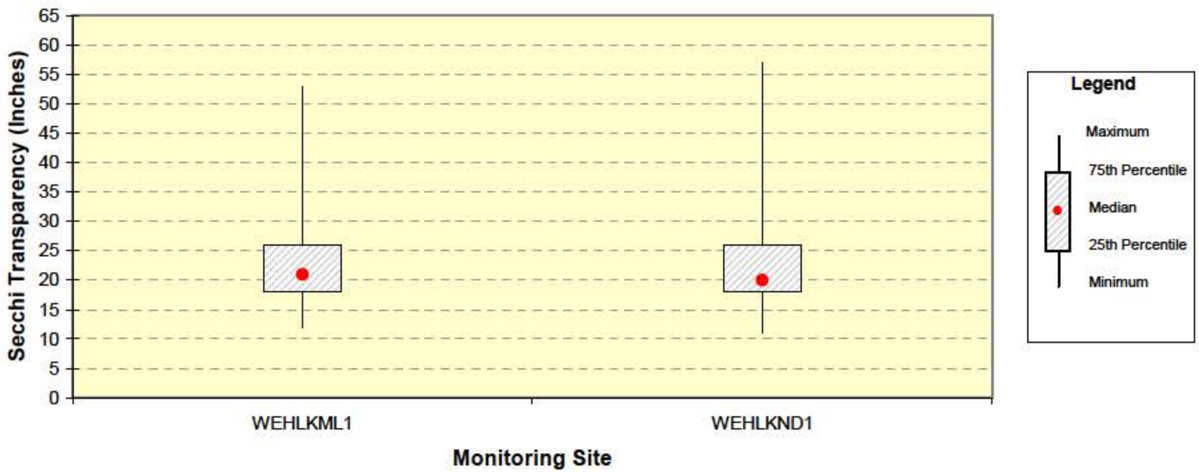

Figure 6.13. Box plot of Secchi depth transparencies measured in Wehrspann Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.1.5.2.1.4.2 <u>Turbidity</u>

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Wehrspann Reservoir from the depth-profile turbidity measurements taken at sites WEHLKND1 and WEHLKML1 during 2006 (Plate 37). As seen in Plate 37, Wehrspann Reservoir did not exhibit much longitudinal variability in turbidity.

6.1.5.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Wehrspann Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site WEHLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 38). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen, varied significantly between the surface and bottom (Plate 38). Near-bottom levels of dissolved oxygen were significantly lower than near-surface levels.

6.1.5.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Wehrspann Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., WEHLKND1). Table 6.6 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Wehrspann Reservoir is in a hypereutrophic condition.

Table 6.6. Summary of Trophic State Index (TSI) values calculated for Wehrspann Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	68	70	55	78
TSI(TP)	25	64	65	41	87
TSI(Chl)	23	71	71	57	85
TSI(Avg1)	25	68	67	58	78
TSI(Avg2)	23	68	67	58	78

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.1.5.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Wehrspann Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., WEHLKND1). Plate 39 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Wehrspann Reservoir exhibited decreasing transparency, slightly decreasing total phosphorus concentrations, and increasing chlorophyll *a* levels (Plate 39). Over the 27-year period since 1980, Wehrspann Reservoir has moved from a eutrophic to hypereutrophic condition (Plate 39).

6.1.5.3 <u>Existing Water Quality Conditions of Runoff Inflows to Wehrspann Reservoir</u>

6.1.5.3.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Existing water quality conditions in the main tributary inflow to Wehrspann Reservoir was monitored under runoff conditions, during the period of April through September, at two sites WEHNFUSB1 and WEHNFDSB1 (Figure 6.12). Site WEHNFUSB1 was about 1½ miles above the constructed sediment basin/wetland and site WEHNFDSB1 was at the sediment basin/wetland outflow (Figure 6.12). Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plates 40 and 41, respectively, summarize water quality conditions that were monitored at sites WEHNFUSB1 and WEHNFDSB1 under runoff conditions during the period 2002 through 2006.

6.1.5.3.2 Impact of Constructed Sediment Basin/Wetland on Water Quality Conditions of Runoff Inflow

Runoff water quality conditions monitored upstream and downstream of the constructed sediment basin/wetland at sites WEHNFUSB1 and WEHNFDSB1 over the 5-year period 2002 through 2006 were compared. Box plots were used to display the distribution of the collected paired upstream and downstream samples for the following parameters: turbidity, total suspended solids, total phosphorus, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, atrazine, metolachlor, and alachlor (Plate 42). Non-overlapping interquartile ranges of the adjacent upstream and downstream box plots for a parameter were taken to indicate a significant difference between the measurements. Turbidity, total suspended solids, total phosphorus, total Kjeldahl nitrogen, and nitrate-nitrite nitrogen levels during runoff conditions were all significantly higher above the constructed sediment basin/wetland (Plate 42). Total ammonia nitrogen and the three herbicides atrazine, metolachlor, and alachlor tended to be higher above the constructed sediment basin/wetland, but were not significantly different. Measured runoff levels of atrazine and metolachlor upstream of the constructed sediment basin/wetland noticeably spiked in the spring, seemingly after recent applications of the herbicides.

6.2 SALT CREEK WATERSHED PROJECTS

6.2.1 BACKGROUND INFORMATION

6.2.1.1 Salt Creek Watershed Hydrology

Streamflow in the Salt Creek watershed follows a characteristic pattern. Flows are generally low except for brief periods of rise caused by runoff from rainfall events. A snowpack over the basin in early spring can produce a significant rise in flow as a result of snowmelt runoff. During the winter months, streams in the basin are generally frozen over.

6.2.1.2 Corps Tributary Project Reservoirs

Ten Corps tributary projects [Bluestem, Branched Oak, Conestoga, Holmes, Olive Creek, Pawnee, Stagecoach, Twin Lakes (East and West Twin Reservoirs), Wagon Train, and Yankee Hill] are located in the Salt Creek watershed in southeast Nebraska in the vicinity of the City of Lincoln (Figure 6.14). The authorized purposes for all the project reservoirs are flood control, recreation, and fish and wildlife management. Table 6.7 gives selected engineering data for the Salt Creek tributary project reservoirs. Lake restoration projects have recently been completed on Holmes, Olive Creek, Wagon Train and Yankee Hill Reservoirs. Holmes, Olive Creek, and Wagon Train Reservoirs have refilled and Yankee Hill Reservoir is in the process of refilling.

6.2.1.3 Water Quality Standards Classifications and Section 303(d) Listings

The State of Nebraska's water quality standards designates the following beneficial uses to all the Salt Creek tributary project reservoirs: recreation, warmwater aquatic life, agricultural water supply, and aesthetics. None of the reservoirs are used as a public drinking water supply. Designated swimming beaches are present at Branched Oak, Pawnee, Bluestem, and Wagon Train Reservoirs. The State's water quality standards also identify nutrient criteria for lakes and impounded waters based on the categorization of the physical, chemical, and biological characteristics of the waterbody. Under this categorization Bluestem, Branched Oak, Conestoga, East Twin, Olive Creek, Pawnee, Stagecoach, Wagon Train, and Yankee Hill Reservoirs have been included in a common group coded as R13 impounded waters. Holmes and West Twin Reservoirs, respectively, have been included in other groupings coded as R14 and R18 impounded waters.

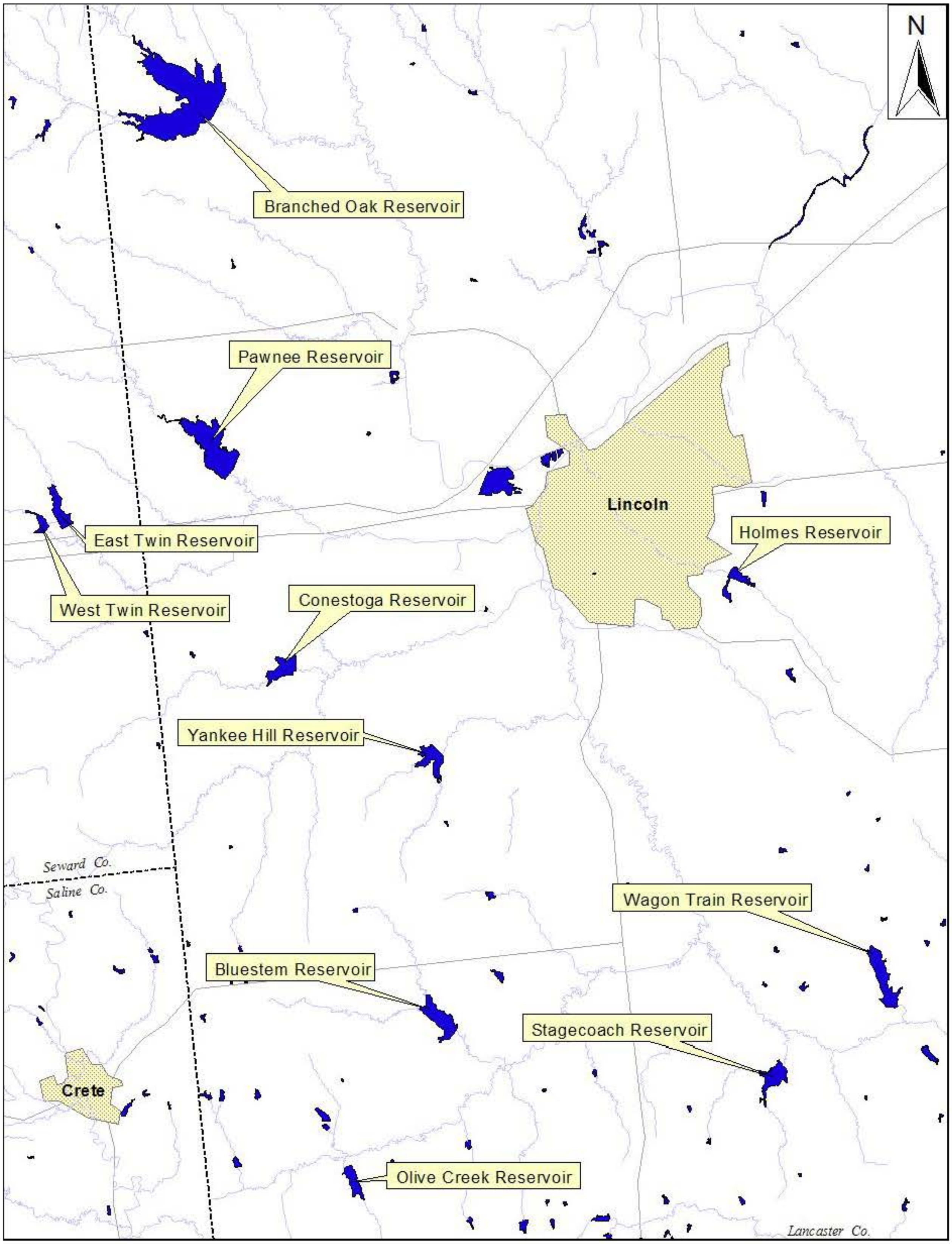

Figure 6.14. Location of the Corps' Salt Creek tributary reservoirs in southeast Nebraska in the vicinity of the City of Lincoln.

Table 6.7. Summary of selected engineering for the Salt Creek Tributary projects.

	Bluestem Reservoir (Dam Site No. 4)	**Branched Oak Reservoir (Dam Site No. 18)**	**Conestoga Reservoir (Dam Site No. 12)**	**Holmes Reservoir (Dam Site No. 17)**
General				
Dammed Stream	N Trib of Olive Branch	Oak Creek	Holmes Creek	Antelope Creek
Drainage Area	16 6 sq mi	89 0 sq mi	15 1 sq mi	5 4 sq mi
Reservoir Length [(1)]	1 6 miles	3 7 miles	1 4 miles	0 7 miles
Conservation Pool Evelation (Top)	1307 4 ft-msl	1284 0 ft-msl	1232 9 ft-msl	1242 4 ft-msl
Date of Dam Closure	12 September 1962	21 August 1967	24 September 1963	17 September 1962
Date of Initial Fill[(2)]	6 July 1963	18 January 1973	May 1965	2 June 1965
"As-Built" Conditions[(3)]	(1964 Survey Data)	(1967 Survey Data)	(1964 Survey Data)	(1963 Survey Data)
Lowest Reservoir Bottom Elevation	1281 ft-msl	1244 ft-msl	1207 ft-msl	1224 ft-msl
Surface Area at top of Conservation Pool	316 ac	1,798 ac	227 ac	123 ac
Capacity to top of Conservation Pool	3,057 ac-ft	26,385 ac-ft	2,472 ac-ft	1,059 ac-ft
Mean Depth at top of Conservation Pool[(4)]	9 7 ft	14 7 ft	10 9 ft	8 6 ft
Latest Surveyed Conditions	(1993 Survey Data)	(1991 Survey Data)	(1996 Survey Data)	(1993 Survey Data)
Lowest Reservoir Bottom Elevation	1288 ft-msl	1252 ft-msl	1216 ft-msl	1228 ft-msl
Surface Area at top of Conservation Pool	309 ac	1,847 ac	217 ac	123 ac
Capacity to top of Conservation Pool	2,531 ac-ft	25,088 ac-ft	1,808 ac-ft	783 ac-ft
Mean Depth at top of Conservation Pool[(4)]	8 2 ft	13 6	8 3	6 4 ft
Sediment Deposition in Conservation and Sediment Pools				
Historic Sediment Deposition[(5)]	526 ac-ft	1,297 ac-ft	664 ac-ft	276 ac-ft
Annual Sedimentation Rate[(6)]	1964-1993 17 5 ac-ft/yr	1967-1991 51 9 ac-ft/yr	1964-1996 20 8 ac-ft/yr	1963-1993 8 9 ac-ft/yr
Current Estimated Sediment Deposition[(7)]	754 ac-ft	2,076 ac-ft	872 ac-ft	174 ac-ft[(9)]
Current capacity to top of Conservation Pool[(8)]	2,303 ac-ft	24,310 ac-ft	1,600 ac-ft	885 ac-ft
Percent of "As-Built" capacity to top of the Conservation Pool lost to current estimated sediment deposition	25%	8%	35%	16%
Operational Details – Historic	(1964 – 2006)	(1973-2006)	(1966 – 2006)	(1966 – 2006)
Maximum Recorded Pool Elevation	1316 5 ft-msl 11-Oct-73	1287 9 ft-msl 26-Aug-87	1241 1 ft-msl 24-Mar-87	1250 0 ft-msl 24-Jul-93
Minimum Recorded Pool Elevation	1299 1 ft-msl 28-Oct-91	1278 2 ft-msl 24-Oct-04	1225 8 ft-msl 8-Sep-06	1231 0 ft-msl[(10)] 1-Aug-04
Maximum Recorded Daily Inflow	1,447 cfs 10-Oct-73	3,700 cfs 25-Aug-87	907 cfs 23-Mar-87	604 cfs 24-Jul-93
Maximum Recorded Daily Outflow	342 cfs 12-Oct-73	774 cfs 25-Jul-93	185 cfs 25-Mar-87	187 cfs 29-Jun-83
Average Annual Pool Elevation	1305 8 ft-msl	1283 1 ft-msl	1232 0 ft-msl	1240 7 ft-msl
Average Annual Inflow	4,658 ac-ft	27,248 ac-ft	4,854 ac-ft	3,425 ac-ft
Average Annual Outflow	3,567 ac-ft	21,725 ac-ft	4,126 ac-ft	2,941 ac-ft
Estimated Retention Time[(11)]	0 65 Years	1 12 Years	0 39 Years	0 30 Years
Operational Details – Current[(12)]				
Maximum Recorded Pool Elevation	1303 7 ft-msl 8-Aug-06	1279 8 ft-msl 24-May-06	1228 4 ft-msl 1-Oct-05	1242 7 ft-msl 12-Jun-06
Minimum Recorded Pool Elevation	1301 8ft-msl 16-May-06	1278 7 ft-msl 12-Nov-05	1225 7 ft-msl 8-Sep-06	1239 3 ft-msl 14-Mar-06
Maximum Recorded Daily Inflow	72 cfs 10-Jun-06	182 cfs 21-Sep-06	10 cfs 30-Mar-06	27 cfs 30-Apr-06
Maximum Recorded Daily Outflow	No Outflow	3 cfs 5-Jul-06	No Outflow	8 cfs 13-Jun-06
Total Inflow (% of Normal)	712 ac-ft (15%)	5,036 ac-ft (20%)	129 ac-ft (3%)	851 ac-ft (24%)
Total Outflow (% of Normal)	No Outflow	230 ac-ft (1%)	No Outflow	236 ac-ft (9%)
Outlet Works				
Ungated Outlets	2) 30" x 96" 1313 5 ft-msl 2) 12" x 54" 1307 4 ft-msl	2) 42" x 144" 1284 0 ft-msl	2) 30" x 96" 1242 3 ft-msl 2) 12" x 54" 1232 9 ft-msl	2) 30" x 96" 1249 0 ft-msl 2) 12" x 36" 1242 5 ft-msl
Gated Outlets (Low-level)	1) 36" x 36" 1303 0 ft-msl	1) 48" x 72" 1274 0 ft-msl 1) 10" Dia 1276 3 ft-msl	1) 36" x 36" 1228 0 ft-msl	1) 36" x 36" 1239 0 ft-msl 1) 45" x 45" 1230 6 ft-msl[(13)]

(1) Reservoir length at top of Conservation Pool
(2) First occurrence of reservoir pool elevation to top of Conservation Pool elevation
(3) "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
(4) Mean Depth = Volume ÷ Surface Area
(5) Historic sediment deposition is the difference in reservoir storage capacity to top of Conservation Pool between "as-built" and latest survey
(6) Annualized sedimentation rate based on historic sediment deposition
(7) Current estimated sediment deposition is based on the historic sediment deposition and the annual sedimentation rate over the number of years since the latest survey
(8) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
(9) A lake renovation project was completed at Holmes Reservoir in 2005 and an estimated 200 ac-ft of sediment was removed from the bottom of the reservoir From 1963 to 2004 an estimated 374 ac-ft (276 ac-ft + 11 x 8 9 ac-ft/yr) of sediment was deposited in Holmes Reservoir After the lake renovation project, it is estimated that the sediment deposition in Holmes Reservoir is 174 ac-ft (374 ac-ft - 200 ac-ft)
(10) Reservoir drawn down for lake renovation project
(11) Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
(12) Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006
(13) A new gate was installed in the Holmes Dam outlet works as part of the 2004 Lake renovation Project to allow the reservoir to be drawn down to lower pool elevations

Table 6.7. (Continued).

	Olive Creek Reservoir (Dam Site No. 2)	Pawnee Reservoir (Dam Site No. 14)	Stagecoach Reservoir (Dam Site No. 9)	Twin Lakes East and West Twin Res. (Dam Site No. 13)
General				
Dammed Stream	S Trib of Olive Branch	North Middle Creek	S Trib Of Hickman Branch	Middle Creek
Drainage Area	8 2 sq mi	35 9 sq mi	9 7 sq mi	11 0 sq mi
Reservoir Length[(1)]	1 2 miles	3 0 miles	1 4 miles	1 5 miles
Conservation Pool Evelation (Top)	1335 0 ft-msl	1244 3 ft-msl	1271 1 ft-msl	1341 0 ft-msl
Date of Dam Closure	20 September 1963	16 July 1964	27 August 1963	26 September 1965
Date of Initial Fill[(2)]	30 June 1965	21 June 1967	May 1965	18 March 1969
"As-Built" Conditions[(3)]	(1964 Survey Data)	(1966 Survey Data)	(1964 Survey Data)	(1966 Survey Data)
Lowest Reservoir Bottom Elevation	1316 ft-msl	1209 ft-msl	1252 ft-msl	1316 ft-msl
Surface Area at top of Conservation Pool	169 ac	734 ac	201 ac	245 ac
Capacity to top of Conservation Pool	1,298 ac-ft	8,695 ac-ft	1,770 ac-ft	2,561 ac-ft
Mean Depth at top of Conservation Pool[(4)]	7 7 ft	11 8 ft	8 8 ft	10 5 ft
Latest Surveyed Conditions	(1993 Survey)	(1991 Survey)	(1990 Survey)	(1994 Survey)
Lowest Reservoir Bottom Elevation	1322 ft-msl	1219 ft-msl	1256 ft-msl	1320 ft-msl
Surface Area at top of Conservation Pool	162 ac	725 ac	195 ac	236 ac
Capacity to top of Conservation Pool	1,100 ac-ft	7,500 ac-ft	1,451 ac-ft	2,161 ac-ft
Mean Depth at top of Conservation Pool[(4)]	6 8 ft	10 3 ft	7 4 ft	9 2 ft
Sediment Deposition in Conservation and Sediment Pools				
Historic Sediment Deposition[(5)]	198 ac-ft	1,195 ac-ft	319 ac-ft	400 ac-ft
Annual Sedimentation Rate[(6)]	1964-1993 6 6 ac-ft/yr	1966-1991 46 0 ac-ft/yr	1964-1990 11 8 ac-ft/yr	1966-1994 13 8 ac-ft/yr
Current Estimated Sediment Deposition[(7)]	205 ac-ft[(9)]	1,885 ac-ft	508 ac-ft	566 ac-ft
Current capacity to top of Conservation Pool[(8)]	1,093 ac-ft	6,810 ac-ft	1,262 ac-ft	1,995 ac-ft
Percent of "As-Built" capacity to top of the Conservation Pool lost to current estimated sediment deposition	16%	22%	29%	22%
Operational Details – Historic	(1966 – 2006)	(1968 – 2006)	(1965 – 2006)	(1969 – 2006)
Maximum Recorded Pool Elevation	1342 6 ft-msl 24-Jul-93	1249 1 ft-msl 25-Jul-93	1279 0 ft-msl 11-Oct-73	1346 9 ft-msl 29-Jun-83
Minimum Recorded Pool Elevation	1324 3 ft-msl[(10)] 1-Dec-99	1240 2 ft-msl 14-Oct-79	1259 6 ft-msl 31-Ooct-91	1332 1 ft-msl 31-Oct-91
Maximum Recorded Daily Inflow	920 cfs 23-May-04	1,381 cfs 24-Mar-87	1,030 cfs 23-May-04	632 cfs 13-Jul-93
Maximum Recorded Daily Outflow	188 cfs 24-May-04	420 cfs 25-Jul-93	190 cfs 12-Oct-73	168 cfs 30-Jun-83
Average Annual Pool Elevation	1331 9 ft-msl	1243 7 ft-msl	1270 2 ft-msl	1339 1 ft-msl
Average Annual Inflow	2,363 ac-ft	7,347 ac-ft	3,225 ac-ft	3,821 ac-ft
Average Annual Outflow	1,816 ac-ft	4,974 ac-ft	2,545 ac-ft	3,009 ac-ft
Estimated Retention Time[(11)]	0 60 Years	1 37 Years	0 50 Years	0 66 Years
Operational Details – Current[(12)]				
Maximum Recorded Pool Elevation	1329 8 ft-msl 1-Oct-05	1243 1 ft-msl 24-May-06	1271 1 ft-msl 22-Jun-06	1338 2 ft-msl 3-Oct-05
Minimum Recorded Pool Elevation	1328 1 ft-msl 19-Sep-06	1241 6 ft-msl 20-Sep-06	1270 1 ft-msl 04-Jan-06	1336 6 ft-msl 20-Sep-06
Maximum Recorded Daily Inflow	8 cfs 4-Jun-06	76 cfs 30-Mar-06	23 cfs 21-Jun-06	23 cfs 31-Mar-06
Maximum Recorded Daily Outflow	No Outflow	No Outflow	No Outflow	No Outflow
Total Inflow (% of Normal)	147 ac-ft (6%)	1,623 ac-ft (22%)	524 ac-ft (16%)	309 ac-ft (8%)
Total Outflow (% of Normal)	No Outflow	No Outflow	No Outflow	No Outflow
Outlet Works				
Ungated Outlets	2) 24" x 72" 1340 9 ft-msl 2) 12" x 30" 1335 0 ft-msl	2) 34" x 120" 1244 3 ft-msl	2) 24" x 72" 1277 1 ft-msl 2) 12" x 30" 1271 1 ft-msl	2) 24" x 63" 1341 0 ft-msl
Gated Outlets (Low-level)	1) 36" x 36" 1330 0 ft-msl	1) 42" x 60" 1236 0 ft-msl	1) 36" x 36" 1261 0 ft-msl	1) 42" x 54" 1333 0 ft-msl

(1) Reservoir length at top of Conservation Pool
(2) First occurrence of reservoir pool elevation to top of Conservation Pool elevation
(3) "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
(4) Mean Depth = Volume ÷ Surface Area
(5) Historic sediment deposition is the difference in reservoir storage capacity to top of Conservation Pool between "as-built" and latest survey
(6) Annualized sedimentation rate based on historic sediment deposition
(7) Current estimated sediment deposition is based on the historic sediment deposition and the annual sedimentation rate over the number of years since the latest survey
(8) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
(9) A lake renovation project was completed at Olive Creek Reservoir in 2000 and an estimated 85 ac-ft of sediment was removed from the bottom of the reservoir From 1963 to 1999 an estimated 244 ac-ft (198 ac-ft + 7 x 6 6 ac-ft/yr) of sediment was deposited in Olive Creek Reservoir After the lake renovation project, it is estimated that the sediment deposition in Olive Creek Reservoir is 205 ac-ft (244 ac-ft - 85 ac-ft + 7 x 6 6 ac-ft/yr)
(10) Reservoir drawn down for lake renovation project
(11) Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
(12) Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

Table 6.7. (Continued).

	Wagon Train Reservoir (Dam Site No. 8)	**Yankee Hill Reservoir (Dam Site No. 10)**		
General				
Dammed Stream	N Trib Of Hickman Branch	Cardwell Branch		
Drainage Area	15 6 sq mi	9 7 sq mi		
Reservoir Length[1]	1 8 miles	1 4 miles		
Conservation Pool Evelation (Top)	1287 8 ft-msl	1244 9 ft-msl		
Date of Dam Closure	24 September 1962	27 August 1963		
Date of Initial Fill[2]	24 June 1963	May 1965		
"As-Built" Conditions[3]	(1963 Survey Data)	(1966 Survey Data)		
Lowest Reservoir Bottom Elevation	1261 ft-msl	1226 ft-msl		
Surface Area at top of Conservation Pool	279 ac	216 ac		
Capacity to top of Conservation Pool	2,272 ac-ft	1,907 ac-ft		
Mean Depth at top of Conservation Pool[4]	8 2 ft	8 8 ft		
Latest Surveyed Conditions	(1993 Survey Data)	(1994 Survey Data)		
Lowest Reservoir Bottom Elevation	1272 ft-msl	1231 ft-msl		
Surface Area at top of Conservation Pool	277 ac	211 ac		
Capacity to top of Conservation Pool	1,780 ac-ft	1,627 ac-ft		
Mean Depth at top of Conservation Pool[4]	6 4 ft	7 7 ft		
Sediment Deposition in Conservation and Sediment Pools				
Historic Sediment Deposition[5]	486 ac-ft	280 ac-ft		
Annual Sedimentation Rate[6]	15 7 ac-ft/yr	9 7 ac-ft/yr		
Current Estimated Sediment Deposition[7]	629 ac-ft[8]	150 ac-ft[9]		
Current capacity to top of Conservation Pool[10]	1,643 ac-ft	1,757		
Percent of "As-Built" capacity to top of the Conservation Pool lost to current estimated sediment deposition	28%	15%		
Operational Details – Historic	(1964 – 2006)	(1968 – 2003)		
Maximum Recorded Pool Elevation	1295 4 ft-msl 11-Oct-73	1252 3 ft-msl 11-Oct-73		
Minimum Recorded Pool Elevation	1273 1 ft-msl[11] 5-Apr-00	1232 0 ft-msl[11] 1-Nov-03		
Maximum Recorded Daily Inflow	1,199 cfs 10-Oct-73	690 cfs 10-Oct-73		
Maximum Recorded Daily Outflow	334 cfs 25-Jul-93	145 cfs 12-Oct-73		
Average Annual Pool Elevation	1286 1 ft-msl	1243 7ft-msl		
Average Annual Inflow	4,823 ac-ft	5,478 ac-ft		
Average Annual Outflow	3,905 ac-ft	4,819 ac-ft		
Estimated Retention Time[12]	0 42 Years	0 36 Years		
Operational Details – Current[13]				
Maximum Recorded Pool Elevation	1284 8 ft-msl 1-Oct-05	1232 0 ft-msl[11]		
Minimum Recorded Pool Elevation	1283 9 ft-msl 20-Sep-06	1232 0 ft-msl[11]		
Maximum Recorded Daily Inflow	11 cfs 2-Nov-05	0 cfs[11] (0%)		
Maximum Recorded Daily Outflow	No Outflow	No Outflow		
Total Inflow (% of Normal)	432 ac-ft (9%)	0 ac-ft[11] (0%)		
Total Outflow (% of Normal)	No Outflow	No Outflow		
Outlet Works				
Ungated Outlets	2) 30" x 96" 1292 4 ft-msl 2) 12" x 54" 1287 8 ft-msl	2) 18" x 63" 1250 0 ft-msl 2) 12" x 30" 1244 9 ft-msl		
Gated Outlets (Low-level)	1) 36" x 36" 1283 5 ft-msl	1) 36" x 36" 1237 0 ft-msl		

[1] Reservoir length at top of Conservation Pool
[2] First occurrence of reservoir pool elevation to top of Conservation Pool elevation
[3] "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
[4] Mean Depth = Volume ÷ Surface Area
[5] Historic sediment deposition is the difference in reservoir storage capacity to top of Conservation Pool between "as-built" and latest survey
[6] Annualized sedimentation rate based on historic sediment deposition
[7] Current estimated sediment deposition is based on the historic sediment deposition and the annual sedimentation rate over the number of years since the latest survey
[8] A lake renovation project was completed at Wagon Train Reservoir in 2003 and an estimated 45 ac-ft of sediment was removed from the bottom of the reservoir From 1963 to 2002 an estimated 627 ac-ft (486 ac-ft + 9 x 15 7 ac-ft/yr) of sediment was deposited in Wagon Train Reservoir After the lake renovation project, it is estimated that the accumulated sediment in Wagon Train Reservoir was 582 ac-ft (i e , 627 - 45 ac-ft) Current estimate sedimentation is 582 + 3yrs @ 15 7 = 629 ac-ft
[9] A lake renovation project was completed at Yankee Hill Reservoir in 2005 and an estimated 217 ac-ft of sediment was removed from the bottom of the reservoir From 1966 to 2003 an estimated 367 ac-ft (280 ac-ft + 9 x 9 7 ac-ft/yr) of sediment was deposited in Yankee Hill Reservoir After the lake renovation project, it is estimated that the accumulated sediment in Yankee Hill Reservoir was 150 ac-ft (i e , 367 - 217 ac-ft)
[10] Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
[11] Reservoir drawn down for lake renovation project
[12] Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
[13] Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

Pursuant to the Federal CWA, the State of Nebraska has listed several of the Salt Creek reservoirs as “Category 5” waters on the State’s 2006 Section 303(d) list (see Table 1.3). A “Category 5” listing infers that at least one beneficial use is impaired and a TMDL is required. Salt Creek reservoirs listed as “Category 5” waters include: Bluestem, Conestoga, East Twin, Olive Creek, Stagecoach and West Twin. The beneficial uses impaired include recreation, aquatic life, and aesthetics. The identified pollutants/stressors include: bacteria, nutrients, and sedimentation. TMDLs have been completed for Holmes, Pawnee, Wagon Train, and Yankee Hill Reservoirs.

6.2.2 BLUESTEM RESERVOIR

6.2.2.1 Background Information

6.2.2.1.1 Project Overview

The dam forming Bluestem Reservoir is located on a tributary to the Olive Branch. The dam was completed on September 12, 1962 and the reservoir reached its initial fill on July 6, 1963. The Bluestem Reservoir watershed is 16.6 square miles. The watershed was largely agricultural when the dam was built in 1962 and has remained so to the present time.

6.2.2.1.2 Bluestem Dam Intake Structure

The intake structure at Bluestem Dam is a single reinforced concrete box shaft commonly called a two-way drop inlet. Its inside dimensions are 5 feet by 8 feet. The intake structure has four ungated openings – two 30” x 96” openings with a crest elevation at 1313.5 ft-msl and two 12” x 54” openings with a crest elevation of 1307.4. A 36” x 36” gated opening with a crest elevation at 1303.0 ft-msl was constructed into the upstream wall. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population. It may also be used to release water for downstream needs when the reservoir is below conservation pool.

6.2.2.1.3 Reservoir Storage Zones

Figure 6.15 depicts the current storage zones of Bluestem Reservoir based on the 1993 survey data and estimated sedimentation. It is estimated that 28 percent of the Sediment Pool and 25 percent of the Conservation Pool has been lost to sedimentation as of 2006.

6.2.2.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Bluestem Reservoir since the late 1970’s. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.16 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (BLUNFNRT1 and BLUNFWST1) and the in-reservoir bacteria site (BLULKBACT1) were sampled by the Nebraska Department of Environmental Quality (NDEQ). The other in-reservoir sites (BLULKND1 and BLULKML1) were sampled by the District. The near-dam location (BLULKND1) has been continuously monitored since 1980.

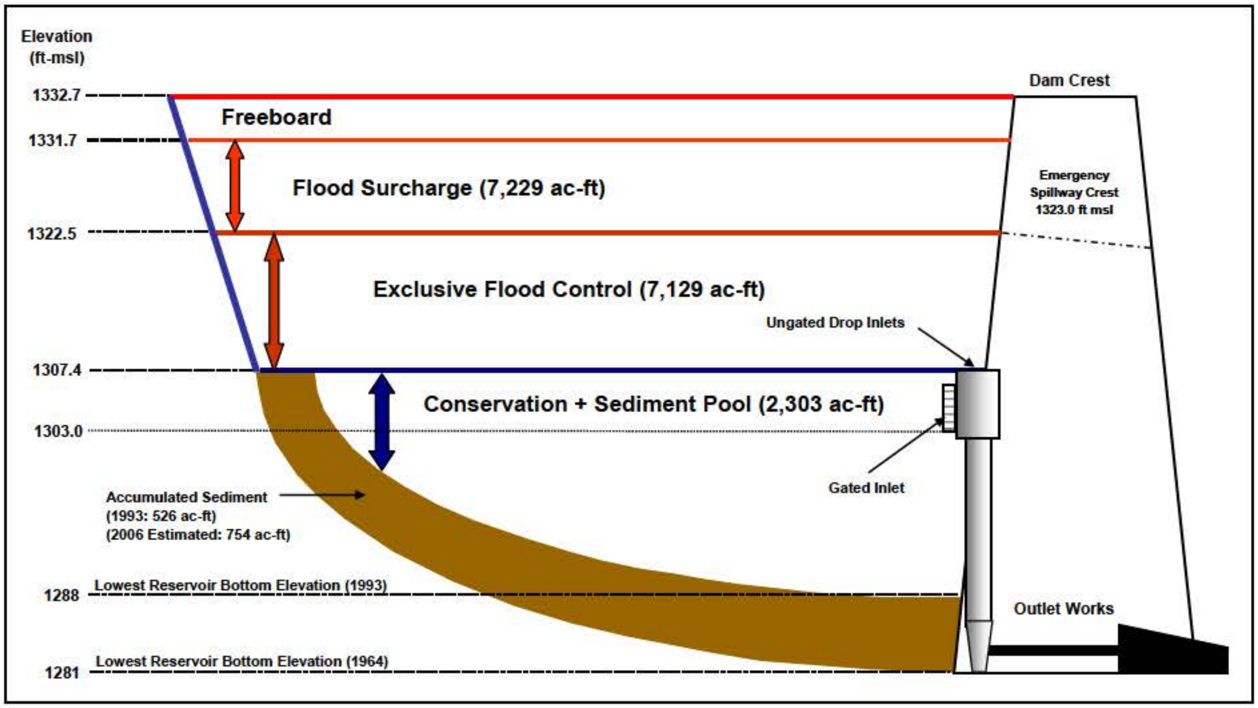

Figure 6.15. Current storage zones of Bluestem Reservoir based on the 1993 survey data and estimated sedimentation.

6.2.2.2 Water Quality in Bluestem Reservoir

6.2.2.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Bluestem Reservoir at sites BLULKND1 and BLULKML1 from May through September during the 5-year period 2002 through 2006 are summarized, respectively, in Plates 43 and 44. A review of these results indicated possible water quality concerns regarding dissolved oxygen and nutrients.

A few dissolved oxygen measurements throughout Bluestem Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 43 and 44). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Bluestem Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three criteria were regularly exceeded throughout the reservoir (Plates 43 and 44).

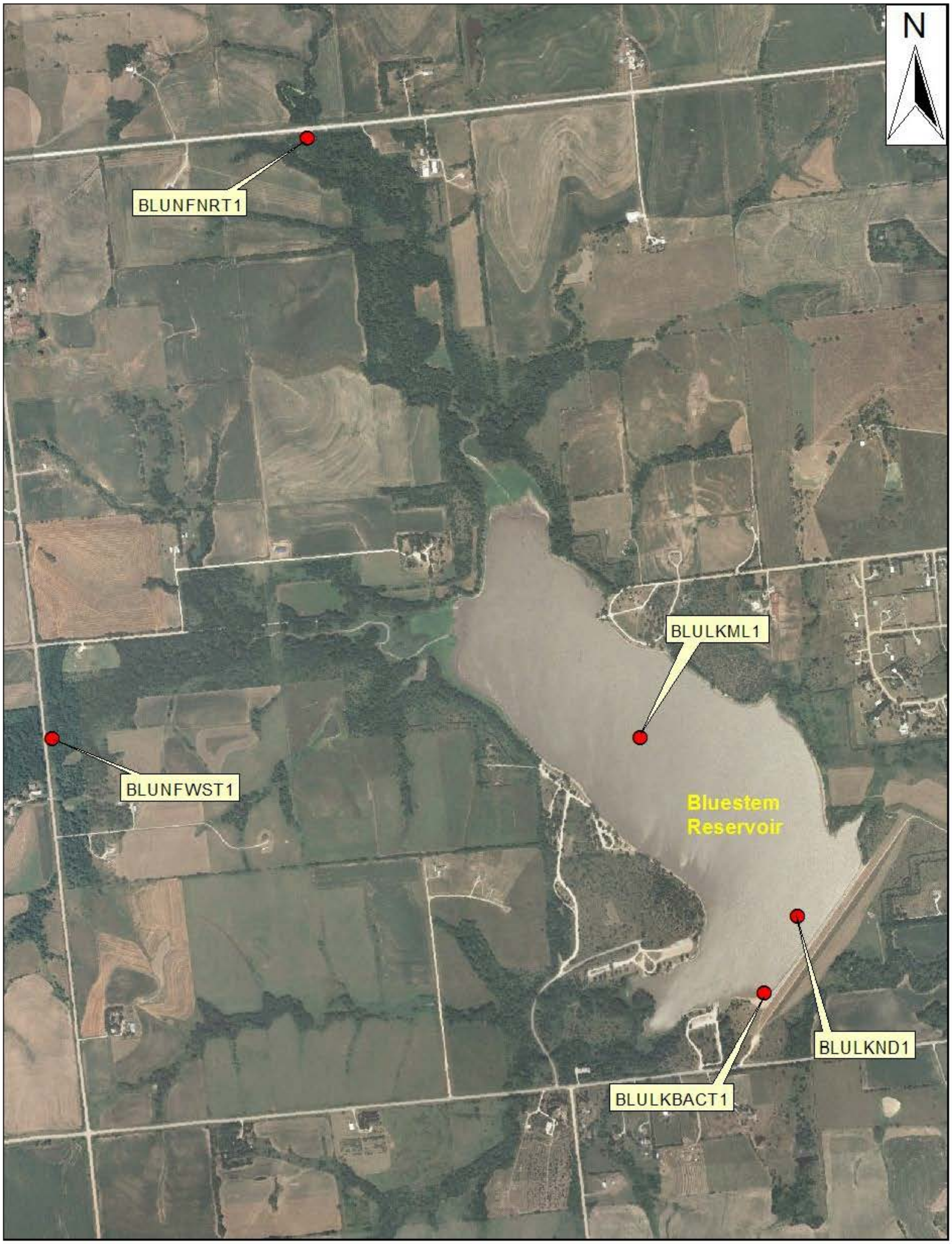

Figure 6.16. Location of sites where water quality monitoring was conducted at Bluestem Reservoir during the period 2002 through 2006.

6.2.2.2.1.2 Summer Thermal Stratification

6.2.2.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Bluestem Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, and September at sites BLULKND1 and BLULKML1 (Plate 45). The contour plots were constructed along the length of the reservoir. Plate 45 indicates that appreciable thermal stratification was not monitored in Bluestem Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 2°C (Plate 45).

6.2.2.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Bluestem Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 46). The plotted depth-profile temperature measurements indicate that the reservoir rarely exhibits significant summer thermal stratification (Plate 46). Based on the rare occurrence of significant thermal stratification in the summer, Bluestem Reservoir appears to be polymixic.

6.2.2.2.1.3 Summer Dissolved Oxygen Conditions

6.2.2.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Bluestem Reservoir based on depth-profile measurements taken in June, July, and September 2006 at sites BLULKND1 and BLULKML1 (Plate 47). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were not monitored in the reservoir. A small volume of water was below 5 mg/l when monitored in June (Plate 47).

6.2.2.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Bluestem Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 48). On a few occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 48). As was noted in discussing the temperature depth-profile plots, Bluestem Reservoir appears to be polymixic, and degraded dissolved oxygen occasionally develop near the reservoir bottom during the summer.

6.2.2.2.1.4 Water Clarity

6.2.2.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.17 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., BLULKND1 and BLULKML1) during the 5-year period 2002 through 2006 (note: the two monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies at the two sites were similar. The Secchi depth transparencies measured at Bluestem Reservoir were the lowest measured at any of the Salt Creek tributary reservoirs

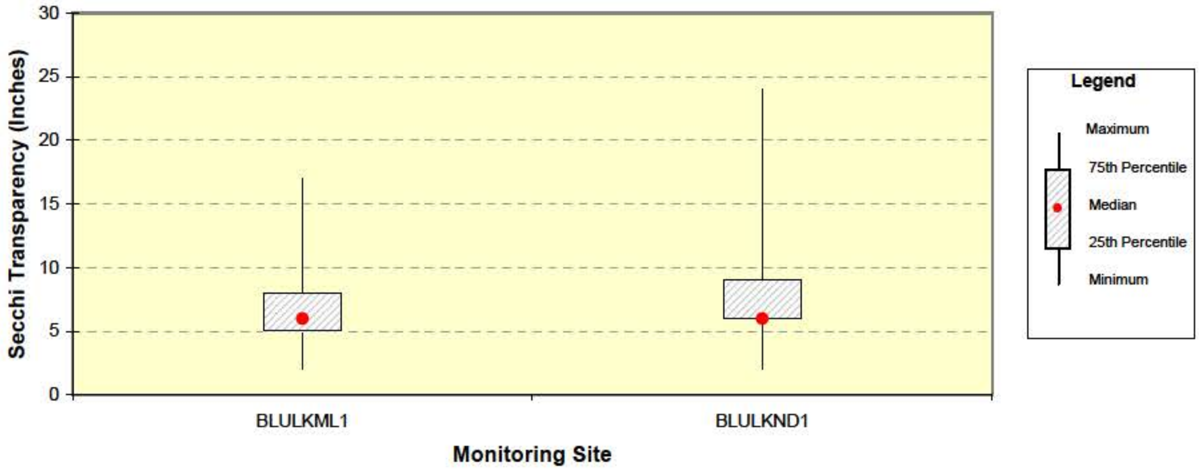

Figure 6.17. Box plot of Secchi depth transparencies measured in Bluestem Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.2.2.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Monthly (i.e., June, July, and September) longitudinal turbidity contour plots were prepared for Bluestem Reservoir from the depth-profile turbidity measurements taken at sites BLULKND1 and BLULKML1 during 2006 (Plate 49). As seen in Plate 49, Bluestem Reservoir did not exhibit much longitudinal variability in turbidity. Relative to the other Salt Creek tributary reservoirs, Bluestem Reservoir can become quite turbid for extended periods following runoff events.

6.2.2.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Bluestem Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site BLULKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 50). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. No parameters varied significantly between the surface and the bottom (Plate 50). Bluestem Reservoir seemingly mixes throughout the water column during the summer, and significant differences in near-surface and near-bottom water quality conditions don't develop.

6.2.2.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Bluestem Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., BLULKND1). Table 6.8 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Bluestem Reservoir is in a hypereutrophic condition.

Table 6.8. Summary of Trophic State Index (TSI) values calculated for Bluestem Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	84	87	67	103
TSI(TP)	25	72	71	52	87
TSI(Chl)	22	57	50	40	85
TSI(Avg1)	25	72	71	62	81
TSI(Avg2)	22	71	71	62	81

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.2.2.1.7 Monitoring at Swimming Beaches

A designated swimming beach is located on Bluestem Reservoir. Bacteria (i.e., *E. coli*) and the cyanobacterial toxin microcystins were monitored at the swimming beach on the reservoir at site BLULKBACT1 by the NDEQ (Figure 6.16). Bacteria were monitored from May through September over the 5-year period 2002 through 2006, and microcystins was monitored from May through September during 2005 and 2006.

6.2.2.2.1.7.1 <u>Bacteria Monitoring</u>

Table 6.9 summarizes the results of the *E. coli* bacteria monitoring. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following *E. coli* bacteria criteria for support of “full-body contact” recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, “full-body contact” recreation was not supported in Bluestem Reservoir during the May through September recreational season. The individual criterion was extended by 21% of the *E. coli* samples, and the geomean criterion was exceeded by 26% of the calculated geomeans during the 5-year period 2002 through 2006. The higher bacteria levels monitored in the reservoir are believed to be associated with runoff situations.

Table 6.9. Summary of weekly (May through September) *E. coli* bacteria samples collected at Bluestem Reservoir (i.e., site BLULKBACT1) during the 5-year period 2002 through 2006.

***E. coli* – Individual Samples**		***E. coli* – Geomeans**	
Number of Samples	105	Number of Geomeans	90
Mean (cfu/100ml)	267	Average	126
Median (cfu/100ml)	26	Median	42
Minimum (cfu/100ml)	1	Minimum	1
Maximum (cfu/100ml)	3,076	Maximum	1,463
Percent of samples exceeding 235/100ml	21%	Number of Geomeans exceeding 126/100ml	26%

6.2.2.2.1.7.2 Microcystins Monitoring

Cyanobacterial toxins are naturally produced substances stored in the cells of certain species of cyanobacteria (i.e., bluegreen algae). These toxins can be harmful to animals, including humans. Cyanobacterial toxins are known to attack the liver (hepatotoxins) or the nervous system (neurotoxins), others simply irritate the skin. These toxins are usually released into the water when the cyanobacteria cell ruptures or dies. One group of toxins produced and released by cyanobacteria are called microcystins because they were isolated from the cyanobacterium *Microcystis aeruginosa*. Microcystins are the most common of the cyanobacterial toxins found in water, as well as being the ones most often responsible for poisoning animals and humans who come into contact with toxic blooms (Health Canada, 2006). Microcystins are a hepatotoxin and are extremely stable in water because of their chemical structure. They can survive in both warm and cold water and can tolerate radical changes in water chemistry, including pH. Over 50 different kinds of the microcystins toxin have been identified.

Due to human health and other environmental concerns, the NDEQ began monitoring for the cyanobacterial toxin microcystins in 2004. The NDEQ has identified a microcystins level of 20 ug/l as a criterion for issuing health advisories and the posting of swimming beaches.

Table 6.10 summarizes the microcystins monitoring conducted at the Bluestem Reservoir swimming beach in 2005 and 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. One sample, 2 percent of the collected samples, exceeded the criterion. The monitored levels of microcystins do not indicate a significant cyanobacterial toxin concern at Bluestem Reservoir.

Table 6.10. Summary of weekly (May through September) microcystins samples collected at the Bluestem Reservoir swimming beach (i.e., site BLULKBACT1) during 2005 and 2006.

Summary Statistic	Swimming Beach (Site BLULKBACT1)
Number of Samples	43
Minimum (ug/l)	0
25^{th} percentile (ug/l)	0.02
Median (ug/l)	0.08
75^{th} Percentile (ug/l)	0.35
Maximum (ug/l)	52.8
Percent of samples exceeding 20 ug/l	2%

6.2.2.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Bluestem Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., BLULKND1). Plate 51 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Bluestem Reservoir exhibited decreasing transparency, increasing total phosphorus concentrations, and slightly decreasing chlorophyll *a* levels (Plate 51). Over the 27-year period since 1980, Bluestem Reservoir remained in a hypereutrophic condition (Plate 51).

6.2.2.2.3 Existing Water Quality Conditions of Runoff Inflows to Bluestem Reservoir

Existing water quality conditions in the main tributary inflows to Bluestem Reservoir were monitored by the NDEQ under runoff conditions, during the period of April through September, at two sites BLUNFNRT1 and BLUNFWST1 (Figure 6.16). Both sites were approximately ½ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plates 52 and 53, respectively, summarize water quality conditions that were monitored at sites BLUNFNRT1 and BLUNFWST1 under runoff conditions during the period 2002 through 2006.

6.2.3 BRANCHED OAK RESERVOIR

6.2.3.1 <u>Background Information</u>

6.2.3.1.1 Project Overview

The dam forming Branched Oak Reservoir is located on Oak Creek. The dam was completed on August 21, 1967 and the reservoir reached its initial fill on January 18, 1973. The Branched Oak Reservoir watershed is 89.0 square miles. The watershed was largely agricultural when the dam was built in 1967 and has remained so to the present time.

6.2.3.1.2 Branched Oak Dam Intake Structure

The Branched Oak Dam intake structure is a single reinforced concrete box shaft commonly called a drop inlet structure. Its inside dimensions are 6 feet by 12 feet. The intake structure has two ungated openings, each 42" x 144" with crest elevations at 1284.0 ft-msl. A 48" x 72" gated opening was constructed into the upstream wall of the inlet structure at a crest elevation of 1274.0 ft-msl. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population. A 10" diameter gated opening is located below the weir on the right side wall of the inlet structure at an elevation of 1276.3 ft-msl. This gate may be used to provide water for downstream requirements.

6.2.3.1.3 Reservoir Storage Zones

Figure 6.18 depicts the current storage zones of Branched Oak Reservoir based on the 1991 survey data and estimated sedimentation. It is estimated that 15 and 8 percent have been respectively lost from the Sediment and Conservation Pools as of 2006.

6.2.3.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Branched Oak Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.19 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (BOKNFNRT1 and BOKNFWST1) and the in-reservoir bacteria sites (BOKLKBACT1 and BOKLKBACT2) were sampled by the NDEQ. The other in-reservoir sites (BOKLKND1, BOKLKMLN1 and BOKLKMLS1) were monitored by the District. The near-dam location (BOKLKND1) has been continuously monitored since 1980.

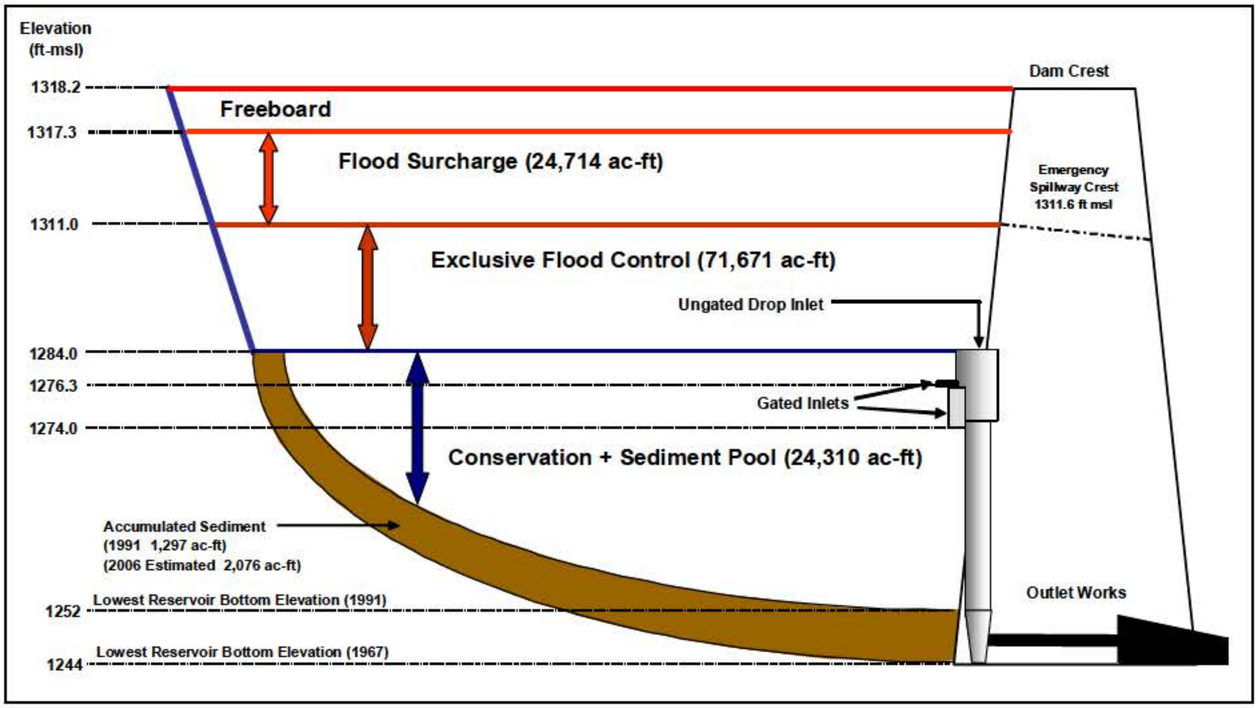

Figure 6.18. Current storage zones of Branched Oak Reservoir based on the 1991 survey data and estimated sedimentation.

6.2.3.2 Water Quality in Branched Oak Reservoir

6.2.3.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.3.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Branched Oak Reservoir at sites BOKLKND1, BOKLKMLN1, and BOKLKMLS1 from May through September during the 5-year period 2002 through 2006 are summarized, respectively, in Plates 54, 55, and 56. A review of these results indicated possible water quality concerns regarding dissolved oxygen, ammonia, and nutrients.

A few dissolved oxygen measurements throughout Branched Oak Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 54 - 56). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Branched Oak Reservoir, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

One sample collected near the dam (i.e., site BOKLKND1) possibly exceeded the chronic ammonia criterion for the protection of warmwater aquatic life (Plate 54). Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

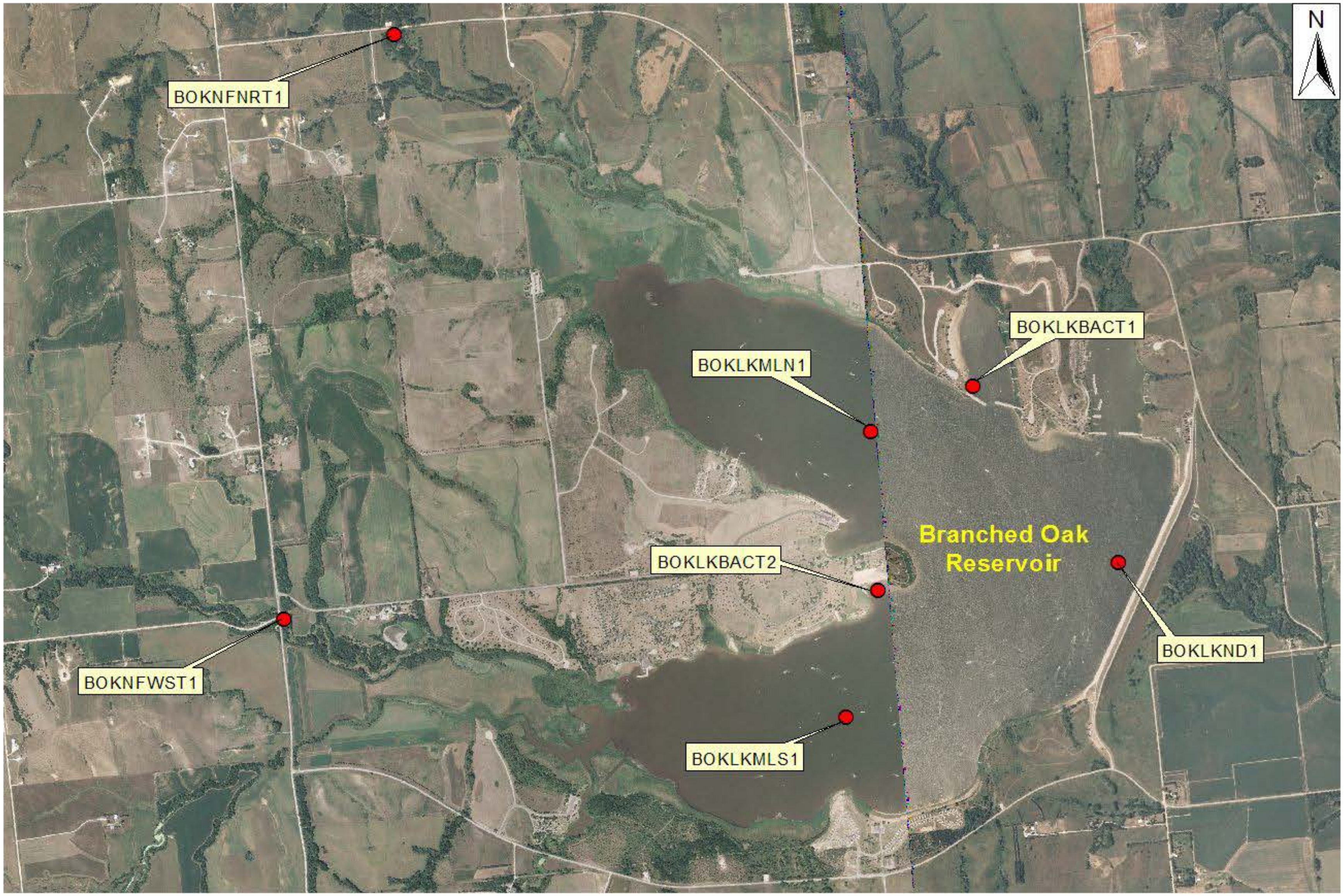

Figure 6.19. Location of sites where water quality monitoring was conducted at Branched Oak Reservoir during the period 2002 through 2006.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). The total nitrogen and chlorophyll *a* criteria were commonly exceeded, with chlorophyll *a* to a much greater extent (Plates 54-56).

6.2.3.2.1.2 Summer Thermal Stratification

6.2.3.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Branched Oak Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites BOKLKND1 and BOKLKMLN1 (Plate 57). The contour plots were constructed along the length of the reservoir through the north arm. Plate 57 indicates that appreciable thermal stratification was not monitored in Branched Oak Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 2°C (Plate 57).

6.2.3.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Branched Oak Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 58). The plotted depth-profile temperature measurements indicate that the reservoir rarely exhibits significant summer thermal stratification (Plate 58). Based on the rare occurrence of significant thermal stratification in the summer, Branched Oak Reservoir appears to be polymixic.

6.2.3.2.1.3 Summer Dissolved Oxygen Conditions

6.2.3.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Branched Oak Reservoir through the north arm based on depth-profile measurements taken in May, July, and September 2006 at sites BOKLKND1 and BOKLKMLN1 (Plate 59). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in the reservoir in July in a small volume of near-bottom water near the dam (Plate 59). Dissolved oxygen conditions below 5 mg/l were monitored in all 3 months (Plate 59).

6.2.3.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Branched Oak Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 60). On a few occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 60). As was noted in discussing the temperature depth-profile plots, Branched Oak Reservoir appears to be polymixic, and degraded dissolved oxygen occasionally develop near the reservoir bottom during the summer.

6.2.3.2.1.4 Water Clarity

6.2.3.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.20 displays a box plot of the Secchi depth transparencies measured at the three in-reservoir monitoring sites (i.e., BOKLKND1, BOKLKMLN1, and BOKLKMLS1) during the 5-year period 2002 through 2006 (note: the monitoring sites are oriented in an upstream to downstream

direction). The Secchi depth transparencies measured at the two upper sites were similar and observably lower than the transparencies measured in the area near the dam (Figure 6.20).

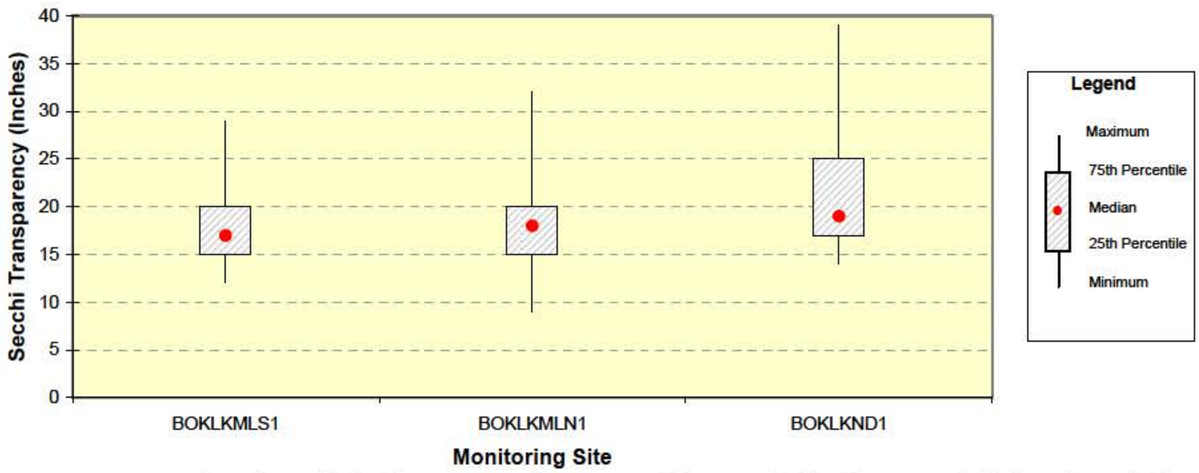

Figure 6.20. Box plot of Secchi depth transparencies measured in Branched Oak Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.3.2.1.4.2 <u>Turbidity</u>

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Branched Oak Reservoir through the north arm from the depth-profile turbidity measurements taken at sites BOKLKND1 and BOKLKMLN1 during 2006 (Plate 61). As seen in Plate 61, Branched Oak Reservoir did not exhibit much longitudinal variability in turbidity. However, there was some vertical variability in turbidity, with deeper waters seemingly being a little more turbid (Plate 61).

6.2.3.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Branched Oak Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site BOKLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrite nitrogen, total phosphorus, and orthophosphorus (Plate 62). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. No parameters varied significantly between the surface and the bottom (Plate 62). Branched Oak Reservoir seemingly mixes throughout the water column during the summer, and significant differences in near-surface and near-bottom water quality conditions don't readily develop.

6.2.3.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Branched Oak Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., BOKLKND1). Table 6.11 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Branched Oak Reservoir is in a slightly hypereutrophic condition.

Table 6.11. Summary of Trophic State Index (TSI) values calculated for Branched Oak Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	70	71	60	75
TSI(TP)	25	64	63	57	84
TSI(Chl)	22	67	68	53	86
TSI(Avg1)	25	67	67	59	76
TSI(Avg2)	22	67	67	59	74

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.3.2.1.7 Monitoring at Swimming Beaches

Two designated swimming beaches are located on Branched Oak Reservoir. Bacteria (i.e., *E. coli*) and the cyanobacterial toxin microcystins were monitored at the two swimming beaches (i.e., sites BOKLKBACT1 and BOKLKBACT2) by the NDEQ during the past 5 years. Bacteria were monitored from May through September over the entire 5-year period, and microcystins was monitored from May through September during 2005 and 2006.

6.2.3.2.1.7.1 <u>Bacteria Monitoring</u>

Table 6.12 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following *E. coli* bacteria criteria for support of "full-body contact" recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation was partially supported in Branched Oak Reservoir during the May through September recreational season. Over the 5-year period, the individual criterion was extended by 11% of the *E. coli* samples at both beaches, and the geomean criterion was respectively exceeded by 5% and 6% of the calculated geomeans at the north and south swimming beaches. The higher bacteria levels monitored in the reservoir are believed to be associated with runoff situations.

6.2.3.2.1.7.2 <u>Microcystins Monitoring</u>

Table 6.13 summarizes the microcystins monitoring conducted at the Branched Oak Reservoir swimming beaches in 2005 and 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. None of the collected samples exceeded the criterion at either of the swimming beaches. Cyanobacterial toxins seemingly are not a concern at Branched Oak Reservoir at this time.

Table 6.12. Summary of weekly (May through September) bacteria samples collected at Branched Oak Reservoir (i.e., sites BOKLKBACT1 and BOKLKBACT2) during the 5-year period 2002 through 2006.

North Swimming Beach Site: BOKLKBACT1			
***E. coli* Bacteria – Individual Samples**		***E. coli* Bacteria – Geomeans**	
Number of Samples	103	Number of Geomeans	87
Mean (cfu/100ml)	138	Average	49
Median (cfu/100ml)	35	Median	38
Minimum (cfu/100ml)	1	Minimum	3
Maximum (cfu/100ml)	2,419	Maximum	135
Percent of samples exceeding 235/100ml	11%	Number of Geomeans exceeding 126/100ml	5%
South Swimming Beach Site: BOKLKBACT2			
***E. coli* Bacteria – Individual Samples**		***E. coli* Bacteria – Geomeans**	
Number of Samples	103	Number of Geomeans	88
Mean (cfu/100ml)	191	Average	34
Median (cfu/100ml)	27	Median	21
Minimum (cfu/100ml)	1	Minimum	2
Maximum (cfu/100ml)	8,164	Maximum	174
Percent of samples exceeding 235/100ml	11%	Number of Geomeans exceeding 126/100ml	6%

Table 6.13. Summary of weekly (May through September) microcystins samples collected at Branched Oak Reservoir (i.e., sites BOKLKBACT1 and BOKLKBACT2) during 2005 and 2006.

Summary Statistic	North Swimming Beach (Site BOKLKBACT1)	South Swimming Beach (Site BOKLKBACT2)
Number of Samples	43	43
Minimum (ug/l)	0	0
25^{th} percentile (ug/l)	0.09	0.08
Median (ug/l)	0.15	0.17
75^{th} Percentile (ug/l)	0.27	0.41
Maximum (ug/l)	3.45	4.68
Percent of samples exceeding 20 ug/l	0%	0%

6.2.3.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Branched Oak Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., BOKLKND1). Plate 63 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Branched Oak Reservoir exhibited decreasing transparency, increasing total phosphorus concentrations and chlorophyll *a* levels (Plate 63). Over the 27-year period since 1980, Branched Oak Reservoir moved from a eutrophic to slightly hypereutrophic condition (Plate 63).

6.2.3.2.3 Existing Water Quality Conditions of Runoff Inflows to Branched Oak Reservoir

Existing water quality conditions in the main tributary inflows to Branched Oak Reservoir were monitored by the NDEQ under runoff conditions, during the period of April through September, at two sites BOKNFNRT1 and BOKNFWST1 (Figure 6.19). Both sites were approximately ½ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plates 64 and 65, respectively, summarize water quality conditions that were monitored at sites BOKNFNRT1 and BOKNFWST1 under runoff conditions during the period 2002 through 2006.

6.2.4 CONESTOGA RESERVOIR

6.2.4.1 Background Information

6.2.4.1.1 Project Overview

The dam forming Conestoga Reservoir is located on Holmes Creek. The dam was completed on September 24, 1963 and the reservoir reached its initial fill in May 1965. The Conestoga Reservoir watershed is 15.1 square miles. The watershed was largely agricultural when the dam was built in 1963 and has remained so to the present time.

6.2.4.1.2 Conestoga Dam Intake Structure

The dam intake at Conestoga Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 5 feet by 8 feet. The intake structure has four ungated openings – two 30" x 96" openings with a crest elevation at 1242.3 ft-msl and two 12" x 54" openings with a crest elevation at 1232.9. A 36" x 36" gated opening with a crest elevation of 1228.0 ft-msl was constructed into the upstream wall. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population. It may also be used to release water for downstream needs.

6.2.4.1.3 Reservoir Storage Zones

Figure 6.21 depicts the current storage zones of Conestoga Reservoir based on the 1988 survey data and estimated sedimentation. It is estimated that 39 percent of the Sediment/Conservation Pool has been lost to sedimentation as of 2006.

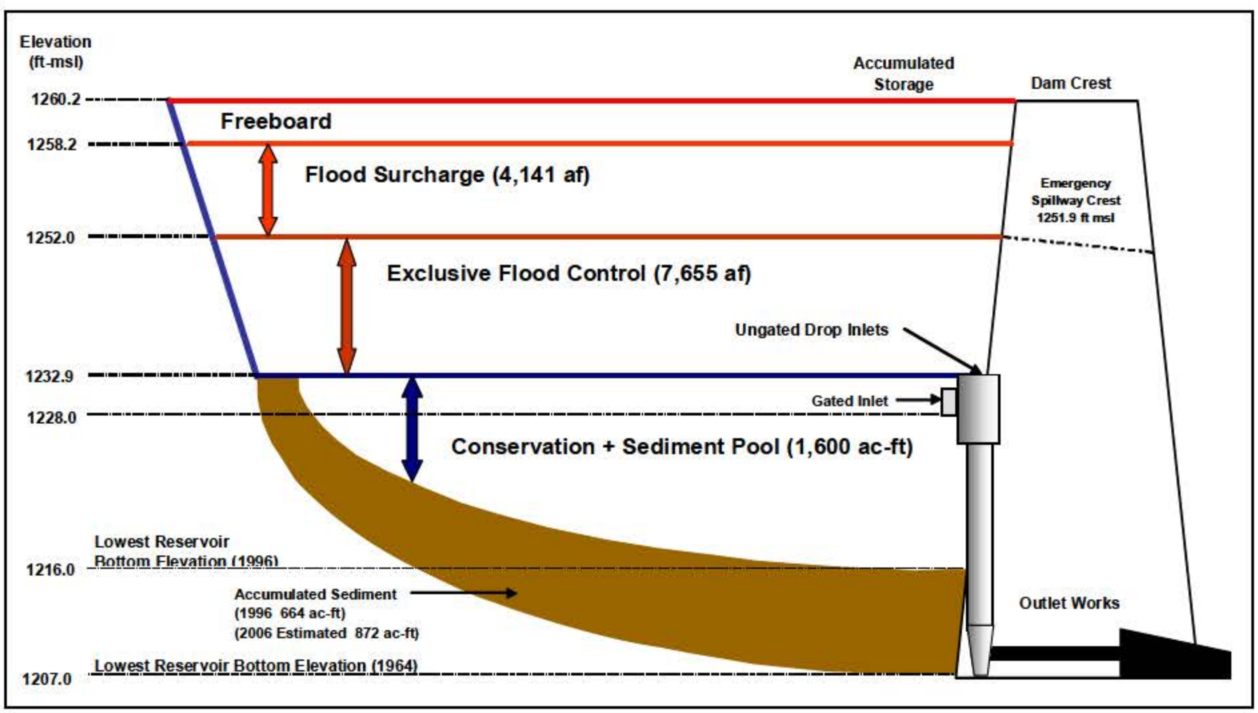

Figure 6.21. Current storage zones of Conestoga Reservoir based on the 1996 survey data and estimated sedimentation.

6.2.4.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Conestoga Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.22 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (CONNFNRT1 and CONNFWST1) and the in-reservoir bacteria site (CONLKBACT1) were sampled by the NDEQ. The other in-reservoir sites (CONLKND1 and CONLKML1) were sampled by the District. The near-dam location (CONLKND1) has been continuously monitored by the District since 1980.

6.2.4.2 <u>Water Quality in Conestoga Reservoir</u>

6.2.4.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.4.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Conestoga Reservoir at sites CONLKND1 and CONLKML1 from May through September during the 5-year period 2002 through 2006 are summarized, respectively, in Plates 66 and 67. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, total ammonia and nutrients.

A small number (≤10%) of dissolved oxygen measurements throughout Conestoga Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 66 and 67). All of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Conestoga Reservoir, and the lower dissolved oxygen levels are not considered to be a water quality standards nonattainment situation.

A small number (≤10%) of pH readings throughout Conestoga Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 66 and 67). The magnitude and small number of pH criterion exceedences are not believed to be a significant concern at this time. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were exceeded throughout the reservoir (Plates 66 and 67). All of the nutrient criteria were exceeded by over half of the appropriate nutrient measurements.

Figure 6.22. Location of sites where water quality monitoring was conducted at Conestoga Reservoir during the period 2002 through 2006.

6.2.4.2.1.2 Summer Thermal Stratification

6.2.4.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Conestoga Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites CONLKND1 and CONLKML1 (Plate 68). Plate 68 indicates that appreciable thermal stratification was not monitored in Conestoga Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 3°C (Plate 68).

6.2.4.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Conestoga Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 69). The plotted depth-profile temperature measurements indicate that the reservoir rarely exhibits significant summer thermal stratification (Plate 69). Based on the rare occurrence of significant thermal stratification in the summer, Conestoga Reservoir appears to be polymixic.

6.2.4.2.1.3 Summer Dissolved Oxygen Conditions

6.2.4.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Conestoga Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites CONLKND1 and CONLKML1 (Plate 70). No anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in the reservoir during the 3 months (Plate 70). Dissolved oxygen conditions below 5 mg/l were monitored in September (Plate 70).

6.2.4.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Conestoga Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 71). On a few occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 71). As was noted in discussing the temperature depth-profile plots, Conestoga Reservoir appears to be polymixic, and degraded dissolved oxygen occasionally develop near the reservoir bottom during the summer.

6.2.4.2.1.4 Water Clarity

6.2.4.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.23 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., CONLKND1 and CONLKML1) during the 5-year period 2002 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies measured at the two sites were similar (Figure 6.23).

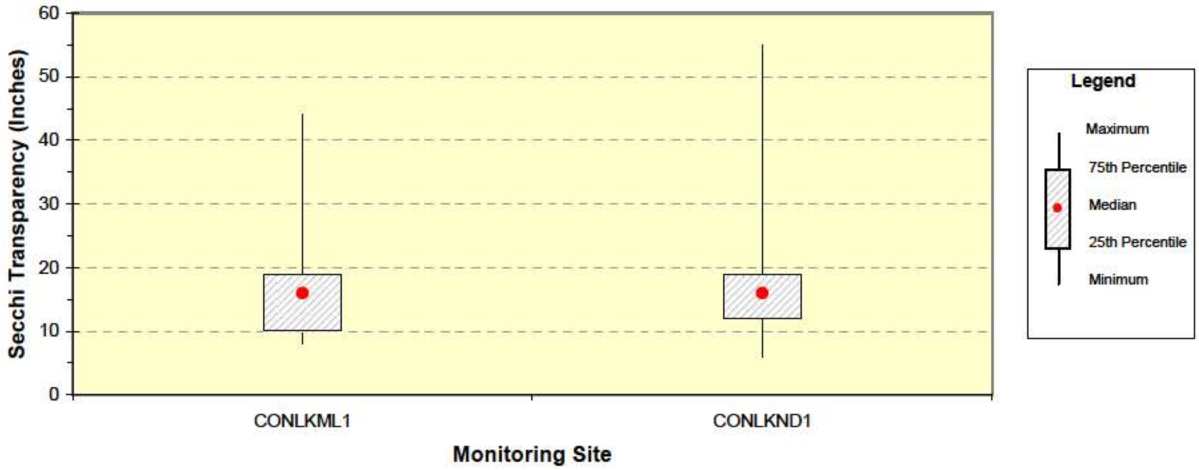

Figure 6.23. Box plot of Secchi depth transparencies measured in Conestoga Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.4.2.1.4.2 Turbidity

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Conestoga Reservoir from the depth-profile turbidity measurements taken at sites CONLKND1 and CONLKML1 during 2006 (Plate 72). As seen in Plate 72, Conestoga Reservoir did exhibit some longitudinal variability in turbidity. Relative to the other Salt Creek tributary reservoirs, Conestoga Reservoir can become quite turbid for extended periods following runoff events. However, Conestoga Reservoir doesn't seem to exhibit turbidity levels as high as those monitored in Bluestem Reservoir.

6.2.4.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Conestoga Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site CONLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 73). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Dissolved oxygen exhibited the biggest difference between the surface and bottom; however, no parameters varied significantly between the surface and the bottom (Plate 73). Conestoga Reservoir seemingly mixes throughout the water column during the summer, and significant differences in near-surface and near-bottom water quality conditions don't readily develop.

6.2.4.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Conestoga Reservoir were calculated from monitoring data collected during the 5-year period 2002 through 2006 at the near-dam ambient monitoring site (i.e., CONLKND1). Table 6.14 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Conestoga Reservoir is in a hypereutrophic condition.

Table 6.14. Summary of Trophic State Index (TSI) values calculated for Conestoga Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	72	73	55	87
TSI(TP)	25	68	69	57	76
TSI(Chl)	24	71	69	50	100
TSI(Avg1)	25	70	70	60	84
TSI(Avg2)	24	71	71	60	84

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.4.2.1.7 Monitoring at Swimming Beaches

A designated swimming beach is located on Conestoga Reservoir. Bacteria (i.e., *E. coli*) and the cyanobacterial toxin microcystins were monitored at the swimming beach on the reservoir at site CONLKBACT1 by the NDEQ (Figure 6.16). Bacteria were monitored from May through September over the 5-year period 2002 through 2006, and microcystins was monitored from May through September during 2005 and 2006.

6.2.4.2.1.7.1 Bacteria Monitoring

Table 6.15 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following *E. coli* bacteria criteria for support of "full-body contact" recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation is supported in Conestoga Reservoir during the May through September recreational season. The individual criterion was extended by 2% of the *E. coli* samples, and the geomean criterion was not exceeded by any of the 90 calculated geomeans during the 5-year period 2002 through 2006.

Table 6.15. Summary of weekly (May through September) *E. coli* bacteria samples collected at Conestoga Reservoir (i.e., site CONLKBACT1) during the 5-year period 2002 through 2006.

E. coli **– Individual Samples**		***E. coli*** **– Geomeans**	
Number of Samples	105	Number of Geomeans	90
Mean (cfu/100ml)	34	Average	6
Median (cfu/100ml)	4	Median	4
Minimum (cfu/100ml)	1	Minimum	1
Maximum (cfu/100ml)	1,733	Maximum	30
Percent of samples exceeding 235/100ml	2%	Number of Geomeans exceeding 126/100ml	0%

6.2.4.2.1.7.2 Microcystins Monitoring

Table 6.16 summarizes the microcystins monitoring conducted at the Conestoga Reservoir swimming beach in 2005 and 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. Nine samples, 21 percent of the collected samples, exceeded the criterion. The monitored levels of microcystins seemingly indicate a cyanobacterial toxin concern may exist at Conestoga Reservoir. It is noted that all of the samples exceeding the criterion were collected in 2005, all of the 22 weekly samples collected in 2006 had microcystins levels below 20 ug/l.

Table 6.16. Summary of weekly (May through September) microcystins samples collected at the Conestoga Reservoir swimming beach (i.e., site CONLKBACT1) during 2005 and 2006.

Summary Statistic	Swimming Beach (Site CONLKBACT1)
Number of Samples	43
Minimum (ug/l)	0.07
25^{th} percentile (ug/l)	0.37
Median (ug/l)	1.31
75^{th} Percentile (ug/l)	9.30
Maximum (ug/l)	>30
Percent of samples exceeding 20 ug/l	21%

6.2.4.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Conestoga Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., CONLKND1). Plate 74 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, it appears that Conestoga Reservoir exhibited no noticeable change in transparency and increasing total phosphorus concentrations and chlorophyll *a* levels (Plate 74). Over the 27-year period since 1980, Conestoga Reservoir moved from a eutrophic to slightly hypereutrophic condition (Plate 74).

6.2.4.2.3 Existing Water Quality Conditions of Runoff Inflows to Conestoga Reservoir

Existing water quality conditions in the main tributary inflow to Conestoga Reservoir was monitored at site CONNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.22). Site CONNF1 was approximately ½ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 75 summarizes water quality conditions that were monitored at site CONNF1 under runoff conditions during the period 2002 through 2006.

6.2.5 HOLMES RESERVOIR

6.2.5.1 Background Information

6.2.5.1.1 Project Overview

The dam forming Holmes Reservoir is located on Antelope Creek in the City of Lincoln. The dam was completed on September 17, 1962 and the reservoir reached its initial fill on June 2, 1965. The Holmes Reservoir watershed is 5.4 square miles. The watershed was largely agricultural when the dam was built in 1962; however since then, the watershed has undergone extensive urbanization with the growth of Lincoln.

6.2.5.1.2 Aquatic Habitat Improvement and Water Quality Management Project

Over $5.5 million in State and Federal funds was used to by the State of Nebraska to implement a lake restoration project at Holmes Reservoir. The project, completed in 2005, implemented numerous measures to improve the aquatic habitat, water quality, and the fishery of the reservoir. Implemented measures included off-line wetlands east of 70th Street, headwater wetlands north of Pioneers Boulevard, outlet modifications, construction of four jetties, two offshore breakwaters, a wooden fishing pier, three bridges, offset sediment dikes on each reservoir arm, and excavation of the reservoir basin (see Figure 6.25). Approximately 320,750 cubic yards (CY) of sediment was excavated from the reservoir basin; 240,000 CY was completely removed, 61,000 CY was used in jetties and breakwaters, and 20,000 CY was incorporated into wetland construction. The excavation restored an estimated 52% of the original conservation pool volume and increased deep water (i.e. over 10 feet) by 111%. Existing and newly constructed wetlands are expected to reduce sediment loading from 21,877 tons to below 5,000 tons annually. Shoreline features such as jetties and breakwaters have added over 5,000 feet of new, productive shoreline while protecting against erosion. This represents a 21% increase in shoreline length. Collectively, basin excavation, shoreline stabilization features, sediment retention structures, and wetlands are expected to add 87 years to the recreational life of the reservoir. The fish community was also renovated and restocked. To increase recreational fishing opportunities, rainbow trout are annually scheduled for stocking into the south arm of the reservoir each fall and spring.

6.2.5.1.3 Holmes Dam Intake Structure

The dam intake at Holmes Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 5 feet by 8 feet. The intake structure has four ungated openings – two 30” x 96” openings with a crest elevation at 1249.0 ft-msl and two 12” x 36” openings with a crest elevation at 1242.5 ft-msl. A 36” x 36” gated opening with a crest elevation of 1239.0 ft-msl was constructed into the upstream wall. As part of the recent lake renovation project a new low-level gated opening was installed in the drop inlet structure. The new low-level gated opening is 45” x 45” with a crest elevation of 1230.6 ft-msl. The purpose of the new low-level gated opening is to allow for better management of pool elevations for water quality and fishery management. It may also be used to release water for downstream needs.

6.2.5.1.4 Reservoir Storage Zones

Figure 6.24 depicts the current storage zones of Holmes Reservoir based on the 1993 survey data, results of the recent lake renovation project, and estimated sedimentation. After accounting for the sediment removed from the reservoir basin as part of the recent lake renovation project, it is estimated that 22 percent of the Sediment Pool and 16 percent of the Conservation Pool has been lost to sedimentation as of 2006.

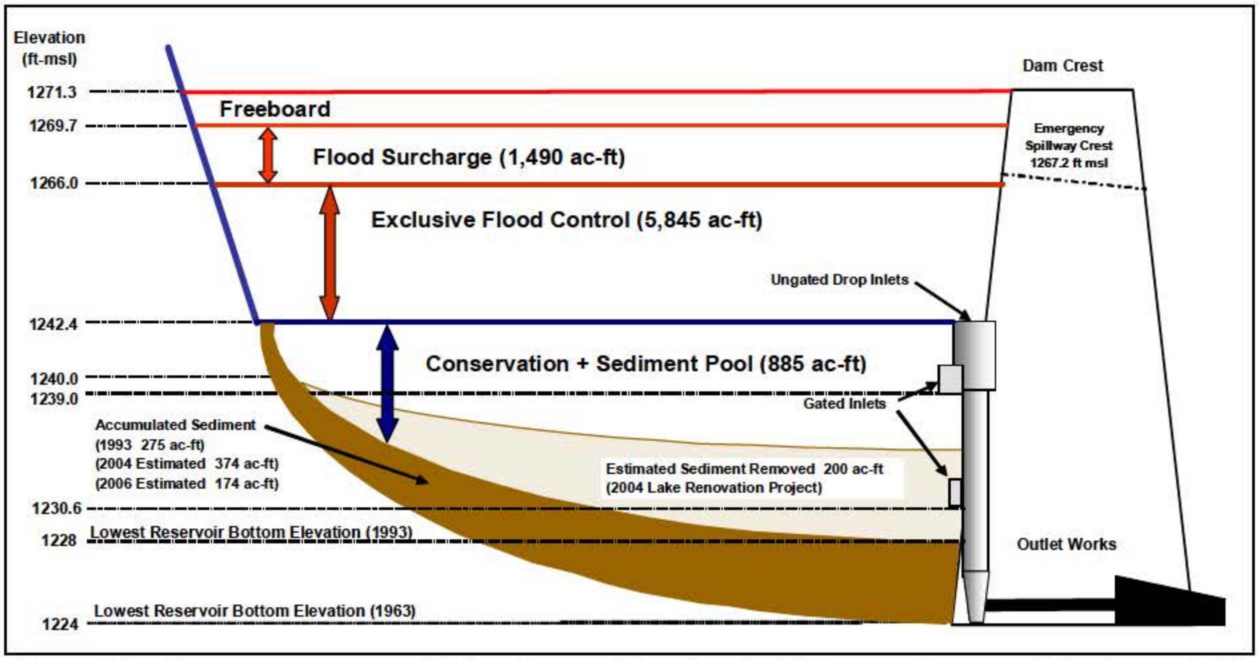

Figure 6.24. Current storage zones of Holmes Reservoir based on the 1993 survey data, recently implemented lake renovation project, and estimated sedimentation.

6.2.5.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Holmes Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.25 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (HOLNFEST1 and HOLNFWST1) and the in-reservoir bacteria site (HOLLKBACT1) were sampled by the NDEQ. The other in-reservoir sites (HOLLKND1, HOLLKMLN1, and HOLLKMLS1) were sampled by the District. The near-dam location (HOLLKND1) has been continuously monitored since 1980.

6.2.5.2 Water Quality in Holmes Reservoir

6.2.5.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.5.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Holmes Reservoir at sites HOLLKND1, HOLLKMLN1, and HOLLKMLS1 from May through September during 2006 are summarized, respectively, in Plates 76 through 78. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, and nutrients.

An appreciable number (≥10%) of pH readings throughout Holmes Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 76 -78). The pH values measured in 2006 also exhibited a large range (i.e., 6.5 - 9.4). It is believed the highly variable pH values are associated with periods of high algal production and CO_2 uptake and release during photosynthesis and respiration. The initial high water clarity in Holmes Reservoir, attributed to the newly completed lake restoration project, allowed for extensive algal production due to the depth of the photic zone and the availability of nutrients.

Figure 6.25. Location of sites where water quality monitoring was conducted at Holmes Reservoir during the period 2002 through 2006.

Nutrient criteria defined in Nebraska's water quality standards for R14 impounded waters include: total phosphorus (134 ug/l), total nitrogen (1,460 ug/l), and chlorophyll *a* (44 ug/l). The total phosphorus and nitrogen criteria were appreciably exceeded (Plate 76).

6.2.5.2.1.2 Summer Thermal Stratification

6.2.5.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Holmes Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, and September at sites HOLLKND1 and HOLLKMLN1 (Plate 79). The contour plots were constructed along the length of the reservoir through the north arm. Plate 79 indicates that appreciable thermal stratification was monitored in Holmes Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 2° to 8°C (Plate 79).

6.2.5.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Holmes Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured during 2006. Depth-profile temperature plots measured during the summer were compiled (Plate 80). The plotted depth-profile temperature measurements indicate that the reservoir occasionally exhibits some thermal stratification (Plate 80). Based on the occasional occurrence of thermal stratification in the summer, Holmes Reservoir appears to be polymixic.

6.2.5.2.1.3 Summer Dissolved Oxygen Conditions

6.2.5.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Holmes Reservoir, through the north arm, based on depth-profile measurements taken in June, July, and September 2006 at sites HOLLKND1 and HOLLKMLN1 (Plate 81). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in the reservoir during July (Plate 81). Hypoxic conditions (i.e., <5 mg/l dissolved oxygen) were also monitored in September (Plate 81). Super-saturated dissolved oxygen conditions were monitored in the upper water column in June and September (Plate 81).

6.2.5.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Holmes Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured during 2006 (Plate 82). On most occasions, there was a significant vertical gradient in summer dissolved oxygen levels in Holmes Reservoir, with the vertical dissolved oxygen profiles exhibiting a clinograde distribution. Most of the summer dissolved oxygen depth profiles measured during 2006 had near-bottom dissolved oxygen concentrations less than 5 mg/l (Plate 82). As was noted in discussing the temperature depth-profile plots, Holmes Reservoir seems to be polymixic and during the summer of 2006 hypoxic conditions developed near the reservoir bottom.

6.2.5.2.1.4 *Water Clarity*

6.2.5.2.1.4.1 Secchi Transparency

Figure 6.26 displays a box plot of the Secchi depth transparencies measured at the three in-reservoir monitoring sites (i.e., HOLLKND1, HOLLKMLN1, and HOLLKMLS1) during 2006. The Secchi depth transparencies measured at all three sites were similar (Figure 6.26).

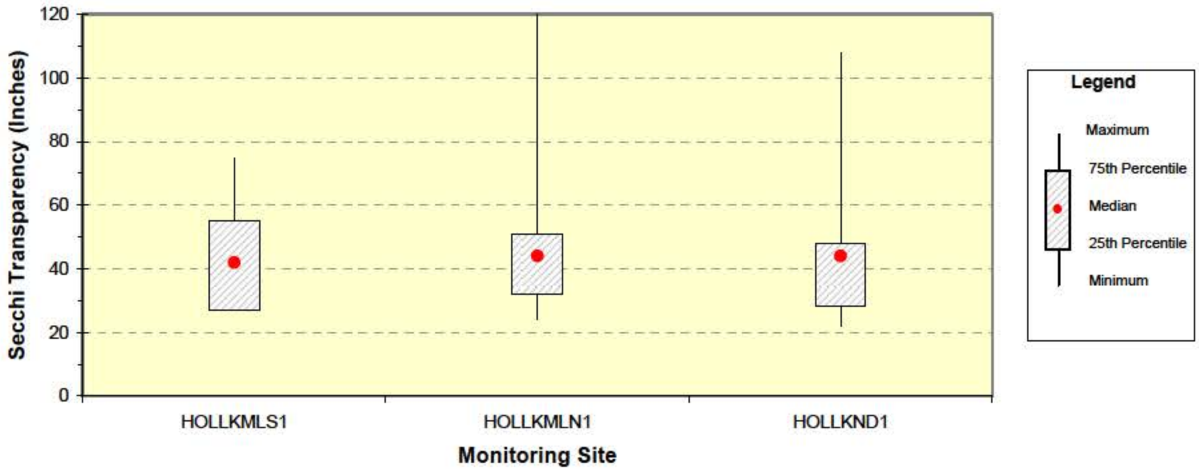

Figure 6.26. Box plot of Secchi depth transparencies measured in Holmes Reservoir during 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.5.2.1.4.2 Turbidity

Monthly (i.e., June, July, and September) longitudinal turbidity contour plots were prepared for Holmes Reservoir through the north arm from the depth-profile turbidity measurements taken at sites HOLLKND1 and HOLLKMLN1 during 2006 (Plate 83). As seen in Plate 83, Holmes Reservoir did not exhibit much longitudinal variability in turbidity. However, there was some vertical variability in turbidity, with deeper waters seemingly being a little more turbid (Plate 83).

6.2.5.2.1.5 *Comparison of Near-Surface and Near-Bottom Water Quality Conditions*

Near-surface and near-bottom water quality conditions monitored in Holmes Reservoir during the summer of 2006 in the near-dam, deepwater area (i.e. site HOLLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, orthophosphorus, and pH (Plate 84). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Three parameters, water temperature, dissolved oxygen, and pH varied significantly between the surface and bottom (Plate 84). Near-bottom water temperatures, dissolved oxygen concentrations, and pH levels were all significantly lower than near-surface conditions. Measured near-bottom oxidation-reduction potential levels approached being significantly lower than near-surface measured levels (Plate 84). The lowest ORP value measured was 60 mV in August.

6.2.5.2.1.6 *Reservoir Trophic Status*

Trophic State Index (TSI) values for Holmes Reservoir were calculated from monitoring data collected during 2006 at the near-dam ambient monitoring site (i.e., HOLLKND1). Table 6.17 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Holmes Reservoir is in a eutrophic condition.

Table 6.17. Summary of Trophic State Index (TSI) values calculated for Holmes Reservoir for 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	5	59	58	45	68
TSI(TP)	5	61	61	55	65
TSI(Chl)	5	59	55	50	74
TSI(Avg)	5	59	60	51	67

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.5.2.1.7 *Monitoring at Swimming Beaches*

A designated swimming beach is not located on Holmes Reservoir; however, the reservoir is used extensively for recreation (e.g., canoeing, kayaking, paddle-boating, wind surfing, etc.). Since these recreational uses can lead to direct contact with water, bacteria and microcystins monitoring was conducted by the NDEQ at the reservoir. During the 2006, bacteria and microcystins samples were collected weekly from June through September on the north shore near the marina on Holmes Reservoir at site HOLLKBACT1 (Figure 6.25).

6.2.5.2.1.7.1 <u>Bacteria Monitoring</u>

Table 6.18 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation was partially supported in Holmes Reservoir during 2006. The individual criterion was extended by 24% of the *E. coli* samples, and the geomean criterion was not exceeded by any of the 13 calculated geomeans during 2006.

Table 6.18. Summary of weekly (June through September) *E. coli* bacteria samples collected at Holmes Reservoir (i.e., site HOLLKBACT1) during 2006.

***E. coli* – Individual Samples**		***E. coli* – Geomeans**	
Number of Samples	17	Number of Geomeans	13
Mean (cfu/100ml)	149	Average	75
Median (cfu/100ml)	47	Median	67
Minimum (cfu/100ml)	5	Minimum	28
Maximum (cfu/100ml)	727	Maximum	121
Percent of samples exceeding 235/100ml	24%	Number of Geomeans exceeding 126/100ml	0%

6.2.5.2.1.7.2 Microcystins Monitoring

Table 6.19 summarizes the microcystins monitoring conducted at Holmes Reservoir in 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. No samples collected at Holmes Reservoir in 2006 exceeded the criterion.

Table 6.19. Summary of weekly (May through September) microcystins samples collected at Holmes Reservoir (i.e., site HOLLKBACT1) during 2006.

Summary Statistic	Swimming Beach (Site CONLKBACT1)
Number of Samples	16
Minimum (ug/l)	0
25th percentile (ug/l)	0.10
Median (ug/l)	0.12
75th Percentile (ug/l)	0.34
Maximum (ug/l)	2.02
Percent of samples exceeding 20 ug/l	0%

6.2.5.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Holmes Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., HOLLKND1). Plate 85 displays a scatter-plot of the collected data for the four parameters and a monotonic linear regression line through 2001. The data gap of 2002 through 2005 is the period when the lake renovation project was implemented at Holmes Reservoir. The 2006 monitoring data reflect conditions after implementation of the lake renovation project. As more “post-project” water quality data is collected, analyses for step trend assessment will be pursued to test for water quality changes from “pre-project” conditions.

6.2.5.2.3 Existing Water Quality Conditions of Runoff Inflows to Holmes Reservoir

Existing water quality conditions in the main tributary inflows to Holmes Reservoir were monitored by the NDEQ under runoff conditions, during the period of April through September, at two sites HOLNFSTH1 and HOLNFEST1. Both sites were less than ¼ mile upstream from the reservoir (Figure 6.25). Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from “base-flow” conditions. Plates 86 and 87, respectively, summarize water quality conditions that were monitored at sites HOLNFSTH1 and HOLNFEST1 under runoff conditions during the period 2002 through 2006.

6.2.6 OLIVE CREEK RESERVOIR

6.2.6.1 Background Information

6.2.6.1.1 Project Overview

The dam forming Olive Creek Reservoir is located on a south tributary of Olive Branch of Salt Creek. The dam was completed on September 20, 1963 and the reservoir reached its initial fill on June

30, 1965. The Olive Creek Reservoir watershed is 8.2 square miles. The watershed was largely agricultural when the dam was built in 1963 and has remained so to the present time.

6.2.6.1.2 Aquatic Habitat Improvement and Water Quality Management Project

A lake renovation project was completed at Olive Creek Reservoir in 2002. The goal of the project was to reduce the quantity of both sediment and nutrients entering the reservoir; to reduce the likelihood of winter fish kills (oxygen depletion); to replace the rough fish dominated community with largemouth bass, bluegill, channel catfish and walleye; and to increase the quantity and quality of shoreline habitat for fish. Approximately $2 million in Federal, State, and Local funding was spent on the lake renovation project.

The lake renovation project consisted of two phases. Phase 1 included excavating approximately 138,000 cubic yards of sediment from the reservoir basin to construct six jetties, three islands, and two offshore breakwaters (see Figure 6.28). The structures collectively added 4,700 feet of shoreline, a 43% increase to the reservoir. In addition, shorelines and bays were reshaped and the outlet structure was modified to allow for minor water level manipulation, all as a means of enhancing aquatic vegetation. Phase 2 was the construction of four sediment basins, two each spanning each of the two main inflowing streams (See Figure 6.28). The basins were created to intercept and slow silt laden runoff following rain events, thus allowing some of the sediment load to settle out before the water reached the main reservoir. Since these basins were located in the flood pool, they occupied flood storage space which had to be mitigated. This was accomplished by excavating an amount of material from behind the basins equal to the amount of space they and their impounded water occupied. The mitigation requirement reduced the reservoir basin excavation by a comparable amount. In addition to the work on the reservoir, other funding was utilized to help implement BMPs (best management practices) in the Olive Creek Reservoir watershed.

6.2.6.1.3 Olive Creek Dam Intake Structure

The dam intake at Olive Creek Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 4 feet by 6 feet. The intake structure has four ungated openings – two 24" x 72" openings with a crest elevation at 1340.9 ft-msl and two 12" x 30" openings with a crest elevation at 1335.0 ft-msl. A 36" x 36" gated opening with a crest elevation of 1330.0 ft-msl was constructed into the upstream wall. As part of the recent lake renovation project a "stop-log" structure was attached to the concrete box shaft over the 36" x 36" gated opening. The 36" x 36" gate is permanently left open and pool levels are managed with the external stop-log structure. The purpose of the gate modification is to allow for better management of pool elevations for water quality and fishery management. The gated outlet may also be used to release water for downstream needs.

6.2.6.1.4 Reservoir Storage Zones

Figure 6.27 depicts the current storage zones of Olive Creek Reservoir based on the 1993 survey data, results of the recent lake renovation project, and estimated sedimentation. After accounting for the sediment removed from the reservoir basin as part of the recent lake renovation project, it is estimated that 22 percent of the Sediment Pool has been lost to sedimentation as of 2006.

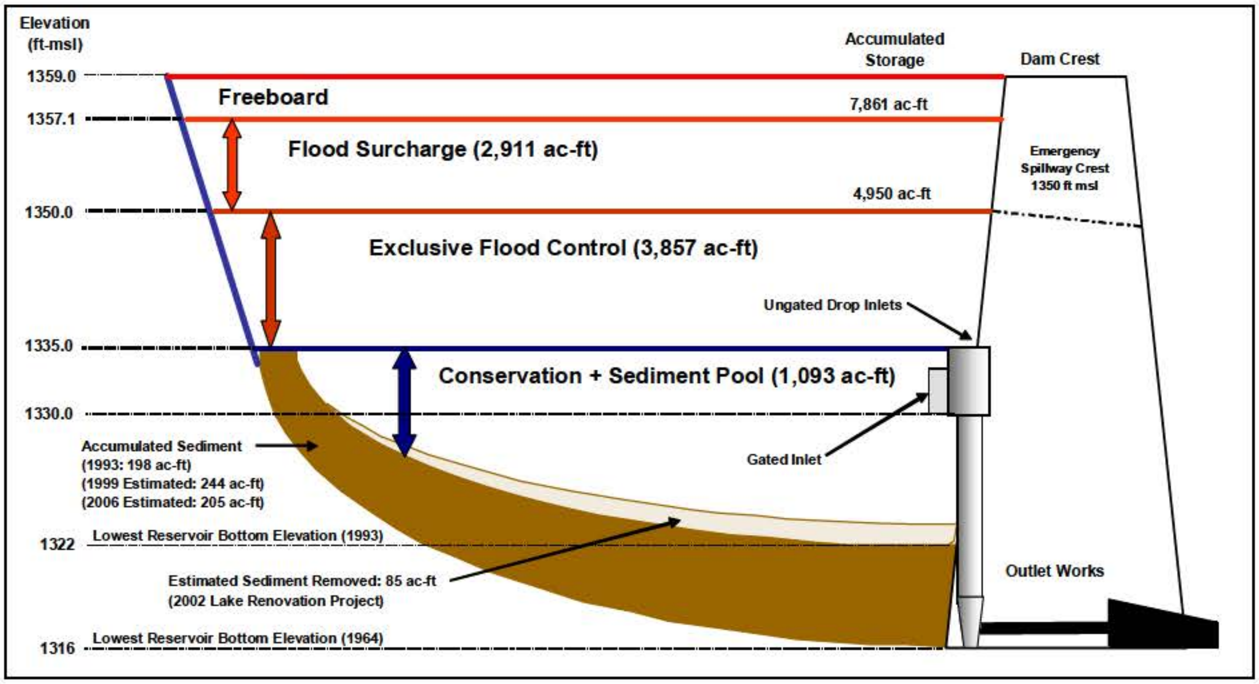

Figure 6.27. Current storage zones of Olive Creek Reservoir based on the 1993 survey data, recently implemented lake renovation project, and estimated sedimentation.

6.2.6.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Olive Creek Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.28 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (OCRNFWST1 and OCRNFEST1) were sampled by the NDEQ. The other in-reservoir sites (OCRLKND1 and OCRLKML1) were sampled by the District. The near-dam location (OCRLKND1) has been continuously monitored since 1980.

6.2.6.2 <u>Water Quality in Olive Creek Reservoir</u>

6.2.6.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.6.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Olive Creek Reservoir at sites OCRLKND1 and OCRLKML1 from May through September during the period 2003 through 2006 are summarized, respectively, in Plates 88 and 89. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, ammonia, nutrients, and arsenic.

An appreciable number (>10%) of dissolved oxygen measurements throughout Olive Creek Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 88 and 89). Given the shallow depth of Olive Creek Reservoir, it is not believed that natural thermal stratification excludes any applicable narrative and numeric criteria. The lower dissolved oxygen levels indicate a possible water quality standards nonattainment situation.

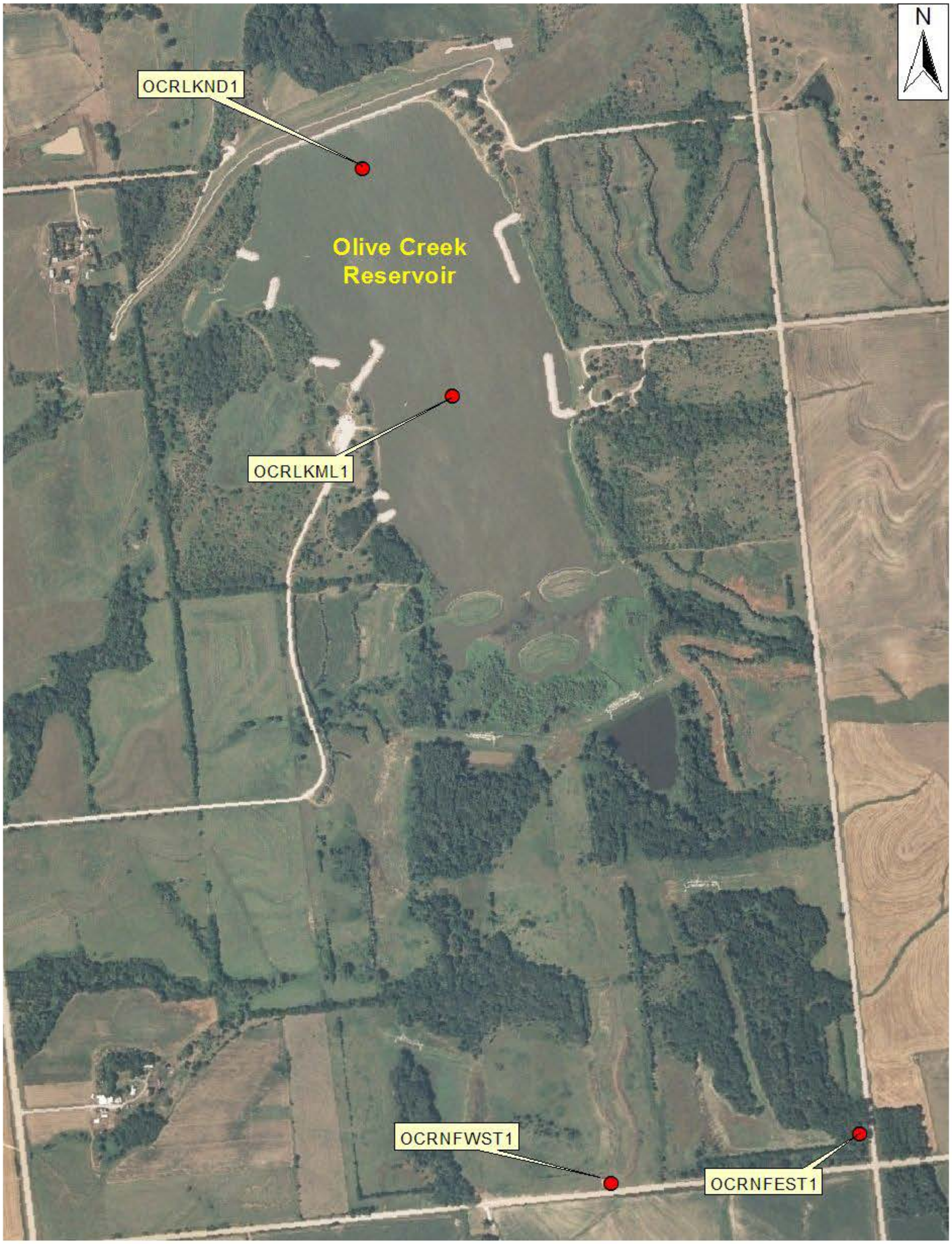

Figure 6.28. Location of sites where water quality monitoring was conducted at Olive Creek Reservoir during the period 2002 through 2006.

A large number (>25%) of pH readings throughout Olive Creek Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 88 and 89). The greatest pH value measured was 10.2 SU. The magnitude and number of pH criterion exceedences indicate a noteworthy water quality concern. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Olive Creek Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were exceeded throughout the reservoir. A majority of the measurements over the 2003 through 2006 period exceeded the nutrient criteria (Plates 88 and 89).

The chronic arsenic criterion for the protection of warmwater aquatic life was exceeded in Olive Creek Reservoir in the area near the dam (Plate 88). Seventy-five percent of the arsenic measurements exceeded the chronic criterion.

6.2.6.2.1.2 Summer Thermal Stratification

6.2.6.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Olive Creek Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, and September at sites OCRLKND1 and OCRLKML1 (Plate 90). Plate 90 indicates that appreciable thermal stratification was not monitored in Olive Creek Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 2°C (Plate 90).

6.2.6.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Olive Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 4 years. Depth-profile temperature plots measured during the summer were compiled (Plate 91). The plotted depth-profile temperature measurements indicate that the reservoir does not exhibit appreciable summer thermal stratification (Plate 91). Since significant summer thermal stratification is not apparent at Olive Creek Reservoir, the reservoir seemingly would regularly mix throughout the water column (i.e., polymixic).

6.2.6.2.1.3 Summer Dissolved Oxygen Conditions

6.2.6.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Olive Creek Reservoir based on depth-profile measurements taken in June, July, and September 2006 at sites OCRLKND1 and OCRLKML1 (Plate 92). No anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in the reservoir during the 3 months (Plate 92). Dissolved oxygen conditions below 5 mg/l occurred in a small area near the dam in June (Plate 92).

6.2.6.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Olive Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 4 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 93). On a few occasions there was a significant vertical gradient in summer dissolved oxygen levels near the dam, and on one occasions anoxic (i.e., < 2 mg/l dissolved oxygen) conditions were present through the entire water column (Plate 93). As was noted in discussing the temperature depth-profile plots, Olive Creek Reservoir appears to be polymixic, but degraded dissolved oxygen occasionally develop during the summer.

6.2.6.2.1.4 Water Clarity

6.2.6.2.1.4.1 Secchi Transparency

Figure 6.29 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., OCRLKND1 and OCRLKML1) during the 4-year period 2003 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies measured at the two sites were similar (Figure 6.29).

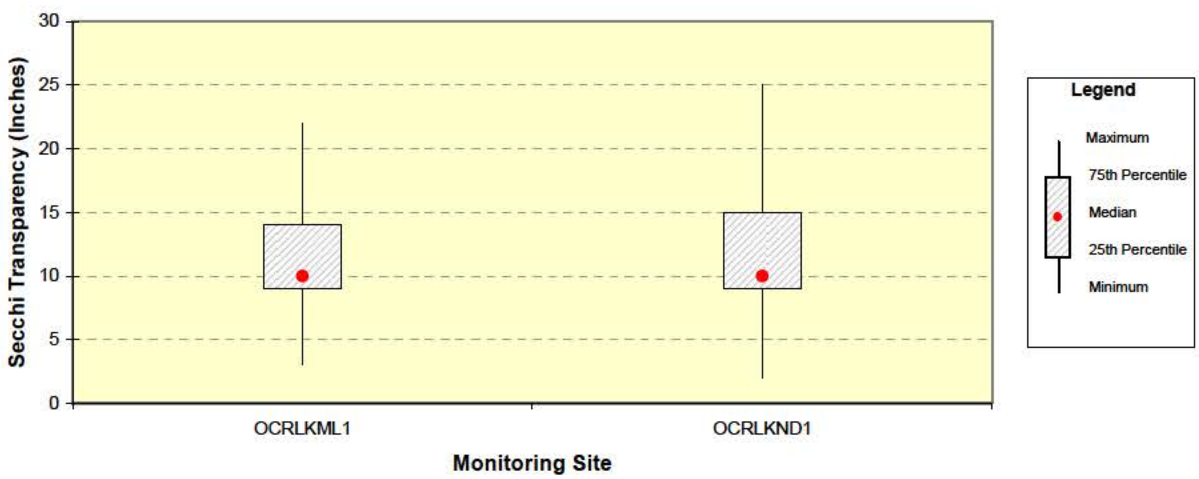

Figure 6.29. Box plot of Secchi depth transparencies measured in Olive Creek Reservoir during the period 2003 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.6.2.1.4.2 Turbidity

Monthly (i.e., June, July, and September) longitudinal turbidity contour plots were prepared for Olive Creek Reservoir from the depth-profile turbidity measurements taken at sites OCRLKND1 and OCRLKML1 during 2006 (Plate 94). As seen in Plate 94, Olive Creek Reservoir did not exhibit much spatial variability in turbidity.

6.2.6.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Olive Creek Reservoir during the summer over the past 4 years in the near-dam, deepwater area (i.e. site OCRLKND1) were compared. Near-surface samples were defined to be samples collected within ½ meter of the reservoir

surface, and near-bottom samples were defined as samples collected within ½ meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 95). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Surface and bottom conditions for the assessed parameters were quite similar (Plate 95). Given its shallow depth, Olive Creek Reservoir seemingly mixes throughout the water column during the summer and significant differences in near-surface and near-bottom water quality conditions do not readily develop.

6.2.6.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Olive Creek Reservoir were calculated from monitoring data collected during the period 2003 through 2006 at the near-dam ambient monitoring site (i.e., OCRLKND1). Table 6.20 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Olive Creek Reservoir is in a eutrophic condition.

Table 6.20. Summary of Trophic State Index (TSI) values calculated for Olive Creek Reservoir for the 4-year period 2003 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	17	70	67	51	83
TSI(TP)	17	67	66	55	85
TSI(Chl)	10	51	52	40	66
TSI(Avg)	18	64	63	56	74

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.
Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.6.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Olive Creek Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., OCRLKND1). Plate 96 displays a scatter-plot of the collected data for the four parameters and a monotonic linear regression lines for the periods 1980 through 1998 and 2003 through 2006. The data gap of 1999 through 2002 is the period when the lake renovation project was implemented at Olive Creek Reservoir. When 5 years of post-project data has been collected, analyses for step trend assessment will be pursued to test for water quality changes from “pre-project” conditions.

6.2.6.2.3 Existing Water Quality Conditions of Runoff Inflows to Olive Creek Reservoir

Existing water quality conditions in the main tributary inflows to Olive Creek Reservoir were monitored by the NDEQ under runoff conditions, during the period of April through September, at two sites OCRNFWST1 and OCRNFEST1 (Figure 6.28). Both sites were about ½ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from “base-flow” conditions. Plates 97 and 98, respectively, summarize water quality conditions that were monitored at sites OCRNFWST1 and OCRNFEST1 under runoff conditions during the period 2002 through 2006.

6.2.7 PAWNEE RESERVOIR

6.2.7.1 Background Information

6.2.7.1.1 Project Overview

The dam forming Pawnee Reservoir is located on North Middle Creek. The dam was completed on July 16, 1964 and the reservoir reached its initial fill on June 21, 1967. The Pawnee Reservoir watershed is 35.9 square miles. The watershed was largely agricultural when the dam was built in 1964 and has remained so to the present time.

6.2.7.1.2 Pawnee Dam Intake Structure

The Pawnee Dam intake structure is a single reinforced concrete box shaft commonly called a drop inlet structure. Its inside dimensions are 5 feet by 10 feet. The intake structure has two ungated openings, each 34" x 120" with crest elevations at 1244.3 ft-msl. A 42" x 60" gated opening was constructed into the upstream wall of the inlet structure at a crest elevation of 1236.0 ft-msl. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population.

6.2.7.1.3 Reservoir Storage Zones

Figure 6.30 depicts the current storage zones of Pawnee Reservoir based on the 1991 survey data and estimated sedimentation. It is estimated that 16 percent of the Sediment Pool has been lost to sedimentation as of 2006.

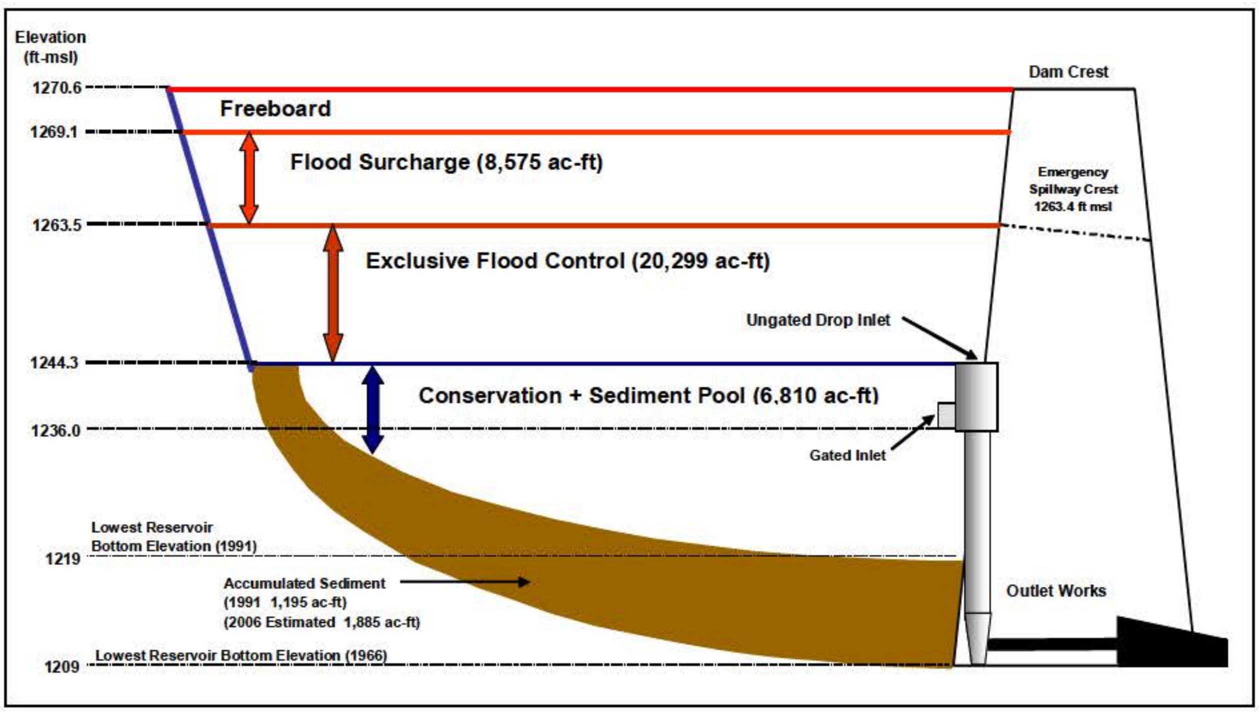

Figure 6.30. Current storage zones of Pawnee Reservoir based on the 1991 survey data and estimated sedimentation.

6.2.7.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Pawnee Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.31 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff site (PAWNF1) and bacteria sites (PAWLKBACT1 and PAWLKBACT2) were sampled by the NDEQ. The other in-reservoir sites (PAWLKND1 and PAWLKML1) were sampled by the District. The near-dam location (PAWLKND1) has been continuously monitored since 1980.

6.2.7.2 <u>Water Quality in Pawnee Reservoir</u>

6.2.7.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.7.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Pawnee Reservoir at sites PAWLKND1 and PAWLKML1 from May through September during the period 2002 through 2006 are summarized, respectively, in Plates 99 and 100. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, ammonia, nutrients, arsenic, and selenium.

An appreciable number (>10%) of dissolved oxygen measurements throughout Pawnee Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 99 and 100). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Pawnee Reservoir, and the measured dissolved oxygen levels below 5 mg/l may not be a water quality standards nonattainment situation.

A few pH readings measured throughout Pawnee Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 99 and 100). The magnitude and number of pH criterion exceedences seemingly do not indicate a significant water quality concern at this time. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Pawnee Reservoir in the area near the dam (Plate 99). Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were regularly exceeded throughout Pawnee Reservoir (Plates 99 and 100).

The chronic arsenic and selenium criteria for the protection of warmwater aquatic life were exceeded in Pawnee Reservoir in the area near the dam (Plate 99). Twenty percent of the arsenic and selenium measurements exceeded the respective chronic criterion.

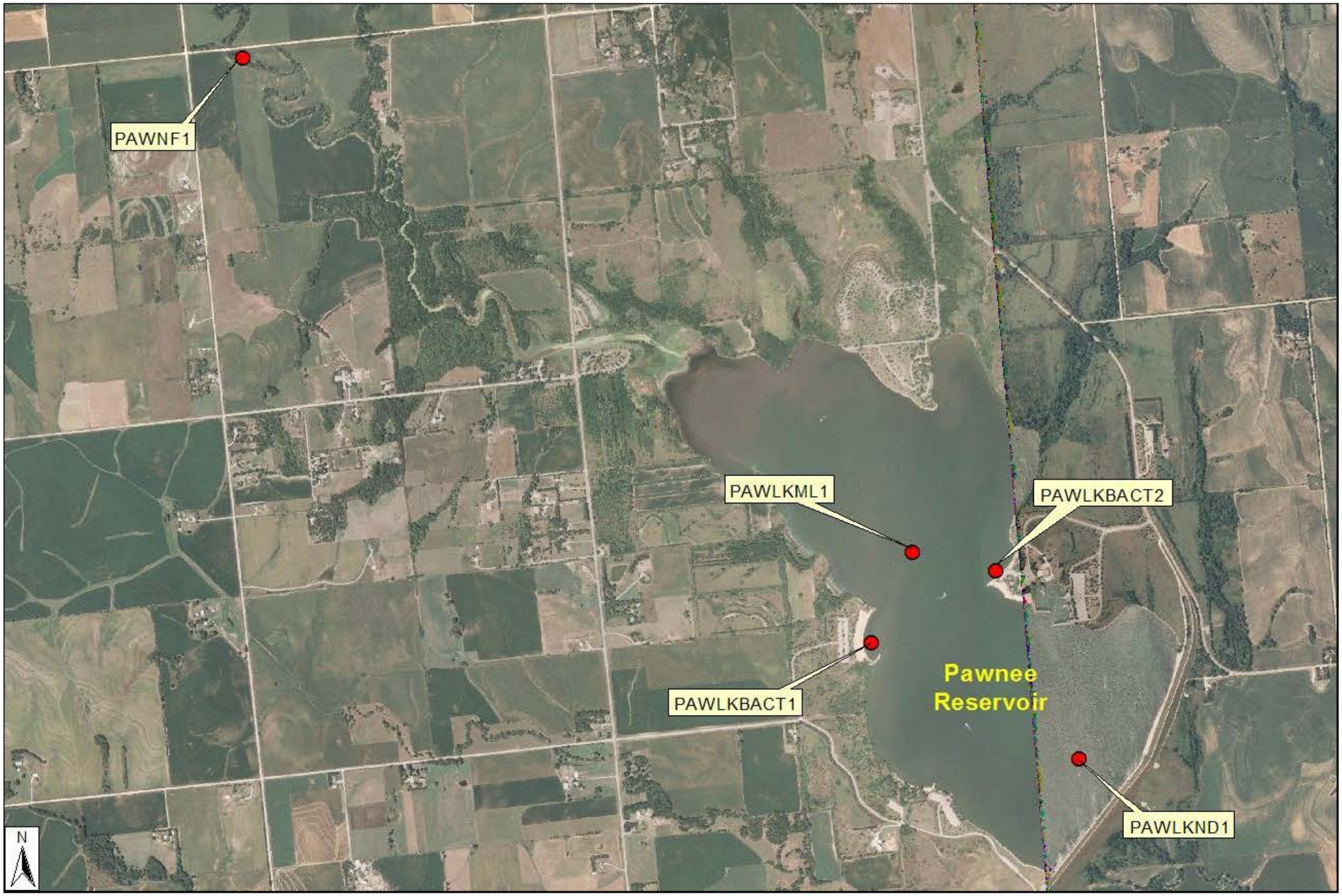

Figure 6.31. Location of sites where water quality monitoring was conducted at Pawnee Reservoir during the period 2002 through 2006.

6.2.7.2.1.2 Summer Thermal Stratification

6.2.7.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Pawnee Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites PAWLKND1 and PAWLKML1 (Plate 101). Plate 101 indicates that appreciable thermal stratification was not monitored in Pawnee Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 2°C (Plate 101).

6.2.7.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Pawnee Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 102). The plotted depth-profile temperature measurements indicate that the reservoir rarely exhibits significant summer thermal stratification (Plate 102). Based on the rare occurrence of significant thermal stratification in the summer, Pawnee Reservoir appears to be polymixic.

6.2.7.2.1.3 Summer Dissolved Oxygen Conditions

6.2.7.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Pawnee Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites PAWLKND1 and PAWLKML1 (Plate 103). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in the reservoir during May and July (Plate 103). Super-saturated dissolved oxygen conditions were monitored in the upper water column in July and September (Plate 103).

6.2.7.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Pawnee Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 104). On a several occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 104). Even though Pawnee Reservoir appears to be polymixic, severely degraded dissolved oxygen conditions occasionally develop near the reservoir bottom during the summer.

6.2.7.2.1.4 Water Clarity

6.2.7.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.32 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., PAWLKND1 and PAWLKML1) during the 5-year period 2002 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies measured at the upper site were observably lower than the transparencies measured in the area near the dam (Figure 6.32).

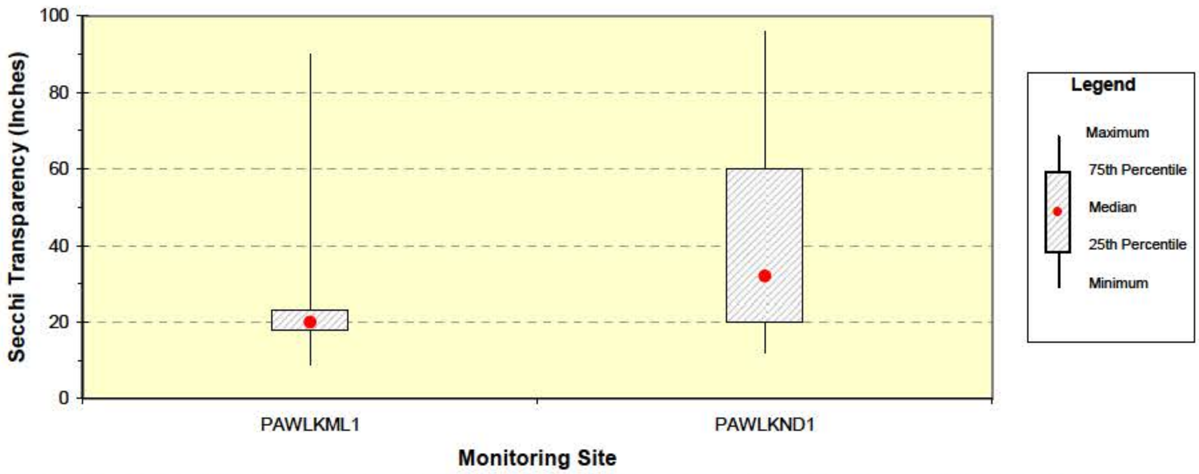

Figure 6.32. Box plot of Secchi depth transparencies measured in Pawnee Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.7.2.1.4.2 <u>Turbidity</u>

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for Pawnee Reservoir from the depth-profile turbidity measurements taken at sites PAWLKND1 and PAWLKML1 during 2006 (Plate 105). As seen in Plate 105, Pawnee Reservoir did exhibit appreciable vertical and longitudinal variability in turbidity in July.

6.2.7.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Pawnee Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site PAWLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 106). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. No parameters varied significantly between the surface and the bottom; however, measured near-bottom dissolved oxygen levels were observably lower than the levels measured near the surface (Plate 106).

6.2.7.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Pawnee Reservoir were calculated from monitoring data collected during the period 2002 through 2006 at the near-dam ambient monitoring site (i.e., PAWLKND1). Table 6.21 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Pawnee Reservoir is in a eutrophic condition.

Table 6.21. Summary of Trophic State Index (TSI) values calculated for Pawnee Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	24	62	63	47	77
TSI(TP)	25	65	65	52	78
TSI(Chl)	23	66	63	46	85
TSI(Avg)	25	64	64	51	74

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.7.2.1.7 Monitoring at Swimming Beaches

Two designated swimming beaches are located on Pawnee Reservoir. Bacteria (i.e., *E. coli*) and the cyanobacterial toxin microcystins were monitored at the two swimming beaches at sites PAWLKBACT1 and PAWLKBACT2 by the NDEQ during the past 5 years (Figure 6.31). Bacteria were monitored from May through September over the entire 5-year period, and microcystins was monitored from May through September during 2005 and 2006.

6.2.7.2.1.7.1 <u>Bacteria Monitoring</u>

Table 6.22 summarizes the results of the *E. coli* bacteria monitoring. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following *E. coli* bacteria criteria for support of "full-body contact" recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation was fully supported, but possible threatened, in Pawnee Reservoir during the May through September recreational season. Over the 5-year period, the individual criterion was exceeded by less than 10% of the *E. coli* samples at both beaches, and the geomean criterion was respectively exceeded by 0% and 2% of the calculated geomeans at the west and east swimming beaches. The higher bacteria levels monitored in the reservoir are believed to be associated with runoff situations.

6.2.7.2.1.7.2 <u>Microcystins Monitoring</u>

Table 6.23 summarizes the microcystins monitoring conducted at the Pawnee Reservoir swimming beaches in 2005 and 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. Respectively, 40 and 39 percent of the collected samples exceeded the criterion at the west and east swimming beaches. The monitored levels of microcystins indicate a significant concern at Pawnee Reservoir regarding cyanobacterial toxins.

Table 6.22. Summary of weekly (May through September) bacteria samples collected at Pawnee Reservoir (i.e., sites PAWLKBACT1 and PAWLKBACT2) during the 5-year period 2002 through 2006.

West Swimming Beach Site: PAWLKBACT1			
***E. coli* – Individual Samples**		***E. coli* – Geomeans**	
Number of Samples	81	Number of Geomeans	65
Mean (cfu/100ml)	37	Average	13
Median (cfu/100ml)	10	Median	10
Minimum (cfu/100ml)	1	Minimum	3
Maximum (cfu/100ml)	687	Maximum	75
Percent of samples exceeding 235/100ml	2%	Number of Geomeans exceeding 126/100ml	0%
East Swimming Beach Site: PAWLKBACT2			
***E. coli* – Individual Samples**		***E. coli* – Geomeans**	
Number of Samples	102	Number of Geomeans	83
Mean (cfu/100ml)	75	Average	22
Median (cfu/100ml)	9	Median	10
Minimum (cfu/100ml)	1	Minimum	1
Maximum (cfu/100ml)	2,500	Maximum	179
Percent of samples exceeding 235/100ml	7%	Number of Geomeans exceeding 126/100ml	2%

Table 6.23. Summary of weekly (May through September) microcystins samples collected at Pawnee Reservoir (i.e., sites PAWLKBACT1 and PAWLKBACT2) during the 2005 and 2006.

Summary Statistic	West Swimming Beach (Site PAWLKBACT1)	East Swimming Beach (Site PAWLKBACT2)
Number of Samples	42	44
Minimum (ug/l)	0.16	0.15
25th percentile (ug/l)	2.86	2.30
Median (ug/l)	6.71	6.55
75th Percentile (ug/l)	>25.00	>25.00
Maximum (ug/l)	>25.00	>25.00
Percent of samples exceeding 20 ug/l	40%	39%

6.2.7.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Pawnee Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., PAWLKND1). Plate 107 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Pawnee Reservoir exhibited increasing trends in transparency and total phosphorus, and no noticeable trend in chlorophyll *a* levels (Plate 107). Over the 27-year period since 1980, Pawnee Reservoir has remained in a eutrophic to slightly hypereutrophic condition (Plate 107).

6.2.7.2.3 Existing Water Quality Conditions of Runoff Inflows to Pawnee Reservoir

Existing water quality conditions in the main tributary inflow to Pawnee Reservoir was monitored at site PAWNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.31). Site PAWNF1 was approximately 1 mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 108 summarizes water quality conditions that were monitored at site PAWNF1 under runoff conditions during the period 2002 through 2006.

6.2.8 Stagecoach Reservoir

6.2.8.1 <u>Background Information</u>

6.2.8.1.1 Project Overview

The dam forming Stagecoach Reservoir is located on a tributary of the Hickman Branch. The dam was completed on August 27, 1963 and the reservoir reached its initial fill in May 1965. The Stagecoach Reservoir watershed is 9.7 square miles. The watershed was largely agricultural when the dam was built in 1963 and has remained so to the present time.

6.2.8.1.2 Stagecoach Dam Intake Structure

The dam intake at Stagecoach Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 4 feet by 6 feet. The intake structure has four ungated openings – two 24" x 72" openings with a crest elevation at 1277.1 ft-msl and two 12" x 30" openings with a crest elevation at 1271.1. A 36" x 36" gated opening with a crest elevation of 1261.0 ft-msl was constructed into the upstream wall. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population. It may also be used to release water for downstream needs.

6.2.8.1.3 Reservoir Storage Zones

Figure 6.21 depicts the current storage zones of Stagecoach Reservoir based on the 1990 survey data and estimated sedimentation. It is estimated that 29 percent of the Sediment Pool has been lost to sedimentation as of 2006.

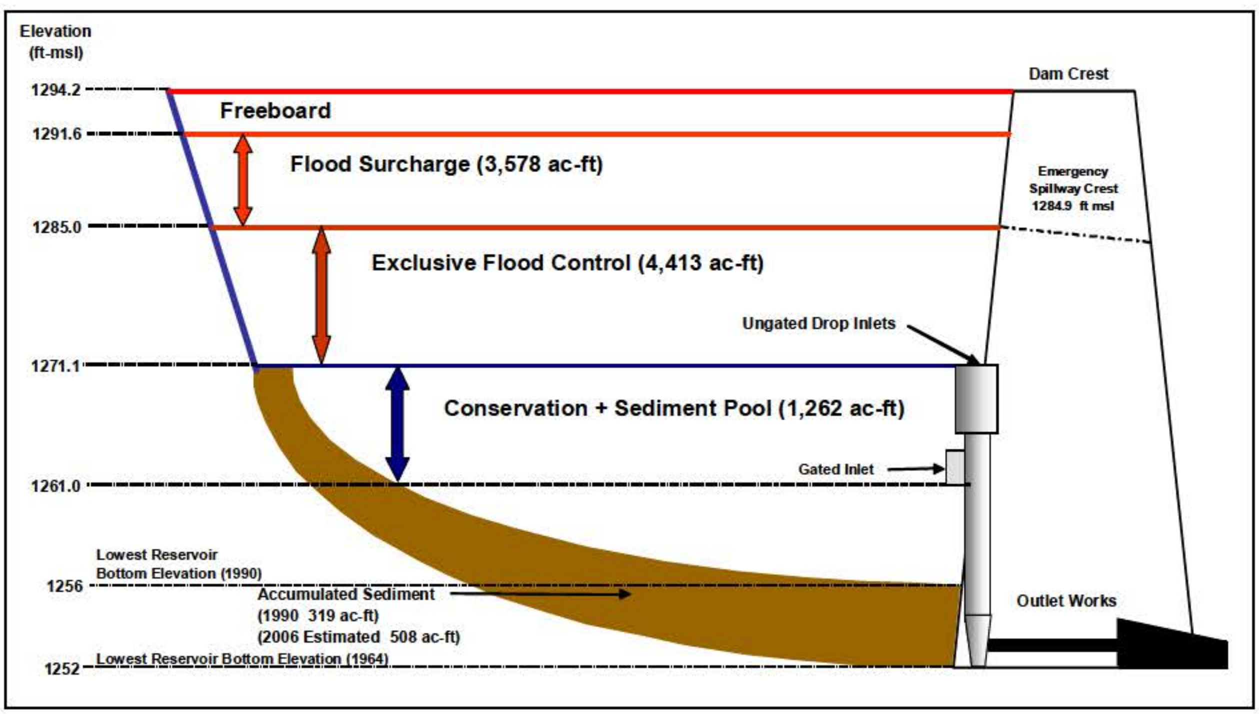

Figure 6.33. Current storage zones of Stagecoach Reservoir based on the 1990 survey data and estimated sedimentation.

6.2.8.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Stagecoach Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.34 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff site (STGNF1) was sampled by the NDEQ. The other in-reservoir sites (STGLKND1 and STGLKML1) were sampled by the District. The near-dam location (STGLKND1) has been continuously monitored since 1980.

6.2.8.2 Water Quality in Stagecoach Reservoir

6.2.8.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.8.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Stagecoach Reservoir at sites STGLKND1 and STGLKML1 from May through September during the period 2002 through 2006 are summarized, respectively, in Plates 109 and 110. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, nutrients, lead, and atrazine.

An appreciable number (>20%) of dissolved oxygen measurements throughout Stagecoach Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 109 and 110). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Stagecoach Reservoir, and the measured dissolved oxygen levels below 5 mg/l may not be a water quality standards nonattainment situation.

A few pH readings measured throughout Stagecoach Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 109 and 110). The magnitude and number of pH criterion exceedences seemingly do not indicate a significant water quality concern at this time. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were regularly exceeded throughout Stagecoach Reservoir (Plates 109 and 110).

The chronic lead and atrazine criteria for the protection of warmwater aquatic life were exceeded in Stagecoach Reservoir in the area near the dam (Plate 109). Twenty percent of the lead and 8 percent of atrazine measurements exceeded the respective chronic criterion.

Figure 6.34. Location of sites where water quality monitoring was conducted at Stagecoach Reservoir during the period 2002 through 2006.

6.2.8.2.1.2 Summer Thermal Stratification

6.2.8.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Stagecoach Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, and September at sites STGLKND1 and STGLKML1 (Plate 111). Plate 111 indicates that appreciable thermal stratification was not monitored in Stagecoach Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 2°C (Plate 111).

6.2.8.2.1.2.2 <u>Near-Dam Temperature Depth-Profile Plots</u>

Existing summer thermal stratification of Stagecoach Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 112). The plotted depth-profile temperature measurements indicate that the reservoir rarely exhibits significant summer thermal stratification (Plate 112). Based on the rare occurrence of significant thermal stratification in the summer, Stagecoach Reservoir appears to be polymixic.

6.2.8.2.1.3 Summer Dissolved Oxygen Conditions

6.2.8.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of Stagecoach Reservoir based on depth-profile measurements taken in June, July, and September 2006 at sites STGLKND1 and STGLKML1 (Plate 113). Dissolved oxygen concentrations < 5 mg/l were monitored in the lower depths of the reservoir in all three months (Plate 113). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored along the bottom of the downstream half of the reservoir during July (Plate 113).

6.2.8.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in Stagecoach Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 114). On a several occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 114). Even though Stagecoach Reservoir appears to be polymixic, severely degraded dissolved oxygen conditions occasionally develop near the reservoir bottom during the summer.

6.2.8.2.1.4 Water Clarity

6.2.8.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.35 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., STGLKND1 and STGLKML1) during the 5-year period 2002 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). The Secchi depth transparencies measured at the two sites were similar (Figure 6.35).

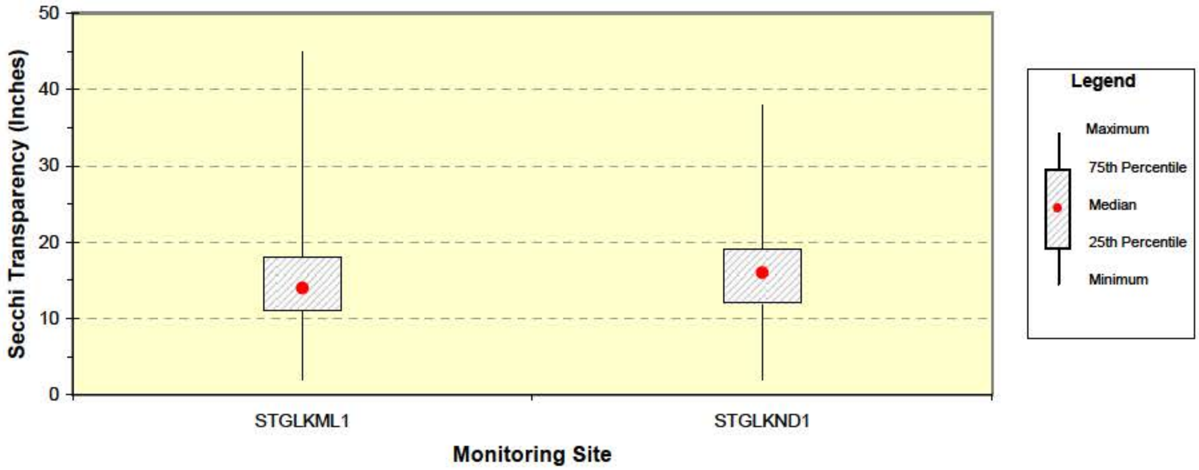

Figure 6.35. Box plot of Secchi depth transparencies measured in Stagecoach Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.8.2.1.4.2 Turbidity

Monthly (i.e., June, July, and September) longitudinal turbidity contour plots were prepared for Stagecoach Reservoir from the depth-profile turbidity measurements taken at sites STGLKND1 and STGLKML1 during 2006 (Plate 115). As seen in Plate 115, Stagecoach Reservoir exhibited some vertical and longitudinal variability in turbidity.

6.2.8.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Stagecoach Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site STGLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 116). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. No parameters varied significantly between the surface and the bottom; however, measured near-bottom dissolved oxygen levels were observably lower than the levels measured near the surface (Plate 116).

6.2.8.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Stagecoach Reservoir were calculated from monitoring data collected during the period 2002 through 2006 at the near-dam ambient monitoring site (i.e., STGLKND1). Table 6.24 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Stagecoach Reservoir is in a hypereutrophic condition.

Table 6.24. Summary of Trophic State Index (TSI) values calculated for Stagecoach Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	24	75	73	61	100
TSI(TP)	25	71	71	61	83
TSI(Chl)	24	66	66	40	87
TSI(Avg)	25	71	70	63	80

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.8.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Stagecoach Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., STGLKND1). Plate 117 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Stagecoach Reservoir exhibited slightly decreasing trends in transparency and chlorophyll *a*, and an increasing trend in total phosphorus levels (Plate 117). Over the 27-year period since 1980, Stagecoach Reservoir has remained in a hypereutrophic condition (Plate 117).

6.2.8.2.3 Existing Water Quality Conditions of Runoff Inflows to Stagecoach Reservoir

Existing water quality conditions in the south tributary inflow to Stagecoach Reservoir was monitored at site STGNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.34). Site STGNF1 was approximately 1 mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 118 summarizes water quality conditions that were monitored at site STGNFSTH1 under runoff conditions during the period 2002 through 2006.

6.2.9 TWIN LAKES RESERVOIR (EAST AND WEST TWIN RESERVOIRS)

6.2.9.1 Background Information

6.2.9.1.1 Project Overview

The dam forming Twin Lakes Reservoir is located on Middle Creek. The dam was completed on September 26, 1965 and the reservoir reached its initial fill on March 18, 1969. Twin Lakes Reservoir is composed of and east and west arm. The two arms of the reservoir basins are connected by a channel. The purpose of the connecting channel is to interconnect the reservoirs of the two embankments so they operate as a single reservoir with one outlet works and one spillway at the east embankment. Under lower pool levels, the two arms are referred to as the separate East and West Twin Reservoirs (see Figure 6.37). The Twin Lakes Reservoir watershed is 11.0 square miles. The watershed was largely agricultural when the dam was built in 1965 and has remained so to the present time.

6.2.9.1.2 Twin Lakes Dam Intake Structure

The dam intake at Twin Lakes is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 42 inches by 63 inches. The intake structure has two 24" x 63" ungated openings with a crest elevation at 1341.0 ft-msl. A 42" x 54" gated opening with a crest elevation of 1333.0 ft-msl was constructed into the upstream wall. The purpose of the gated opening is to lower the level of the conservation pool in order to inspect the conduit, make shoreline repairs, and control fish population. It may also be used to release water for downstream needs.

6.2.9.1.3 Reservoir Storage Zones

Figure 6.36 depicts the current storage zones of Twin Lakes Reservoir based on the 1990 survey data and estimated sedimentation. It is estimated that 31 percent of the Sediment Pool and 22 percent of the Conservation Pool has been lost to sedimentation as of 2006.

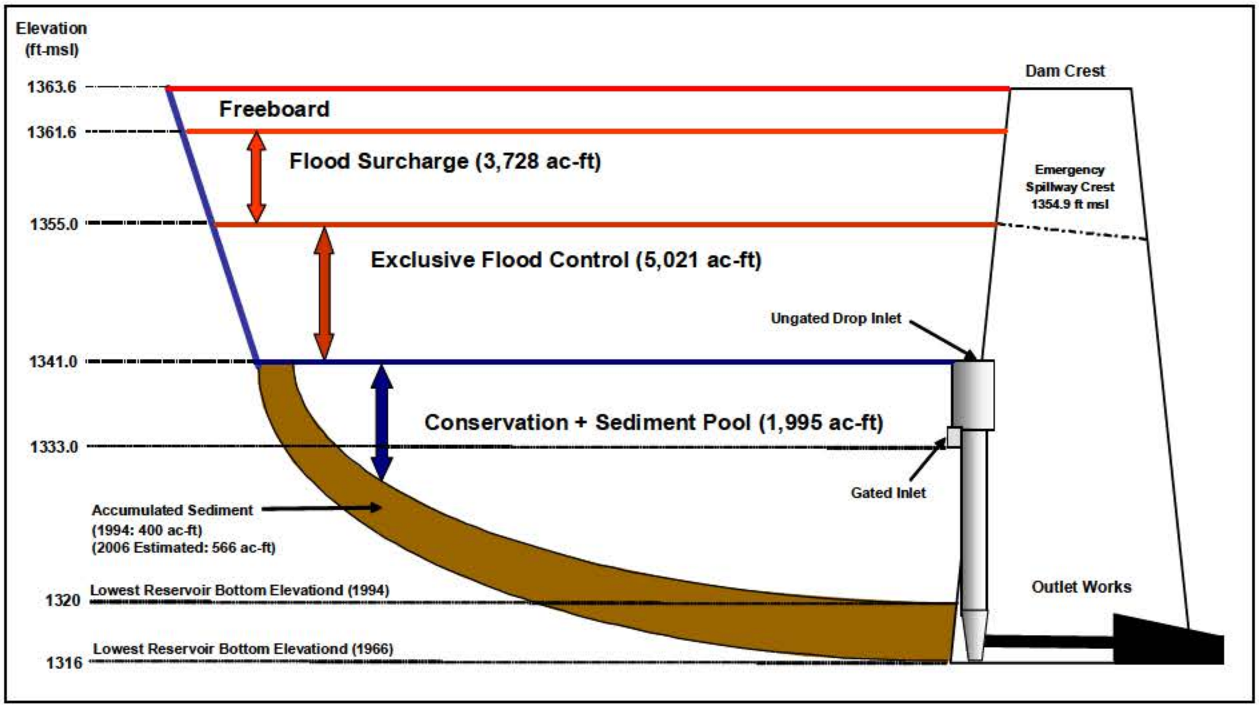

Figure 6.36. Current storage zones of Twin Lakes Reservoir based on the 1994 survey data and estimated sedimentation.

6.2.9.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Twin Lakes Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.37 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff sites (ETNNF1 and WTNNF1) were sampled by the NDEQ. The other in-reservoir sites (ETNLKND1, ETNNF1, and WTNLKND1) were sampled by the District. The near-dam locations (ETNLKD1 and WTNLKND1) have been monitored since 1980.

Figure 6.37. Location of sites where water quality monitoring was conducted at Twin Lakes Reservoir during the period 2002 through 2006.

6.2.9.2 Water Quality in East Twin Reservoir

6.2.9.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.9.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in East Twin Reservoir at sites ETNLKND1 and ETNLKML1 from May through September during the period 2002 through 2006 are summarized, respectively, in Plates 119 and 120. A review of these results indicated possible water quality concerns regarding dissolved oxygen, ammonia, and nutrients.

An appreciable number of dissolved oxygen measurements throughout East Twin Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 119 and 120). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in East Twin Reservoir, and the measured dissolved oxygen levels below 5 mg/l may not be a water quality standards nonattainment situation.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in East Twin Reservoir in the area near the dam (Plate 119). Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were commonly exceeded throughout East Twin Reservoir (Plates 119 and 120).

6.2.9.2.1.2 Summer Thermal Stratification

6.2.9.2.1.2.1 2006 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of East Twin Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, July, and September at sites ETNLKND1 and ETNLKML1 (Plate 121). Plate 121 indicates that appreciable thermal stratification was not monitored in East Twin Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 1° to 3°C (Plate 121).

6.2.9.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of East Twin Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 122). The plotted depth-profile temperature measurements indicate that the reservoir seldom exhibits significant summer thermal stratification (Plate 122). Based on the seldom occurrence of significant thermal stratification in the summer, East Twin Reservoir appears to be polymixic.

6.2.9.2.1.3 Summer Dissolved Oxygen Conditions

6.2.9.2.1.3.1 <u>2006 Monthly Longitudinal Dissolved Oxygen Contour Plots</u>

Dissolved oxygen contour plots were constructed along the length of East Twin Reservoir based on depth-profile measurements taken in May, July, and September 2006 at sites ETNLKND1 and ETNLKML1 (Plate 123). Dissolved oxygen concentrations < 5 mg/l were monitored in the lower depths of the reservoir in all three months (Plate 123). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored along the bottom of the downstream half of the reservoir during May and July (Plate 123).

6.2.9.2.1.3.2 <u>Near-Dam Dissolved Oxygen Depth-Profile Plots</u>

Existing summer dissolved oxygen conditions in East Twin Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 124). On a several occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 124). Even though East Twin Reservoir appears to be polymixic, severely degraded dissolved oxygen conditions occasionally develop near the reservoir bottom during the summer.

6.2.9.2.1.4 Water Clarity

6.2.9.2.1.4.1 <u>Secchi Transparency</u>

Figure 6.38 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., ETNLKND1 and ETNLKML1) during the 5-year period 2002 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). Transparencies measured at the site near the dam were seemingly a little higher than those measured at the mid-lake site (Figure 6.38).

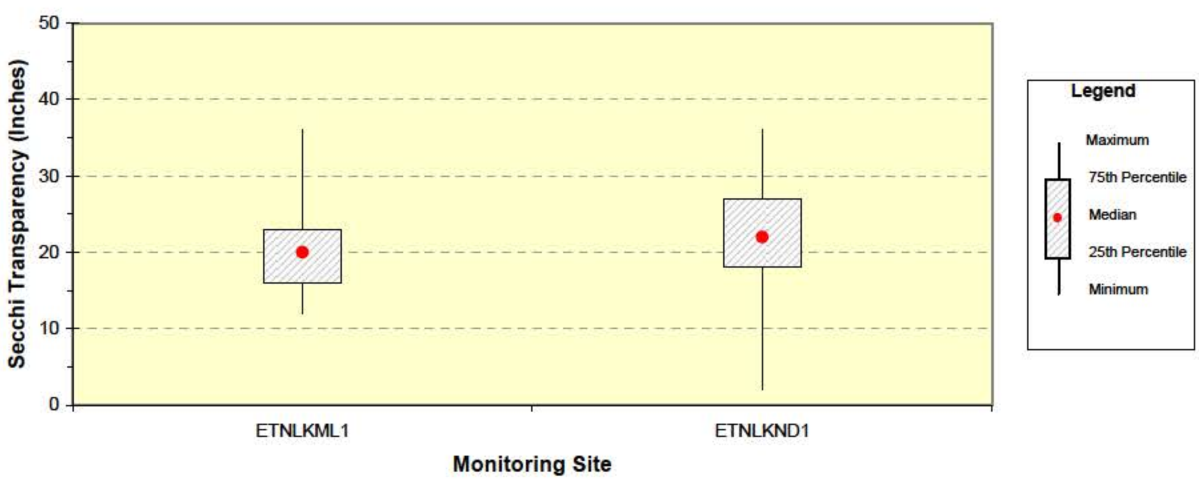

Figure 6.38. Box plot of Secchi depth transparencies measured in East Twin Reservoir during the period 2002 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.9.2.1.4.2 Turbidity

Monthly (i.e., May, July, and September) longitudinal turbidity contour plots were prepared for East Twin Reservoir from the depth-profile turbidity measurements taken at sites ETNLKND1 and ETNLKML1 during 2006 (Plate 125). As seen in Plate 125, East Twin Reservoir exhibited some vertical and longitudinal variability in turbidity.

6.2.9.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in East Twin Reservoir during the summer over the past 5 years in the near-dam, deepwater area (i.e. site ETNLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 126). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen varied significantly between the surface and the bottom (Plate 126). Measured dissolved oxygen concentrations were significantly lower near the reservoir bottom. Although not significantly different, total ammonia nitrogen concentrations appeared to be somewhat higher near the bottom (Plate 126).

6.2.9.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for East Twin Reservoir were calculated from monitoring data collected during the period 2002 through 2006 at the near-dam ambient monitoring site (i.e., ETNLKND1). Table 6.24 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of East Twin Reservoir is in a hypereutrophic condition.

Table 6.25. Summary of Trophic State Index (TSI) values calculated for East Twin Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	69	68	61	100
TSI(TP)	25	63	63	48	77
TSI(Chl)	22	68	68	50	83
TSI(Avg)	25	66	66	58	81

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.9.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for East Twin Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., ETNLKND1). Plate 127 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, East Twin Reservoir exhibited no noticeable trends in transparency, total phosphorus, or chlorophyll *a*. Over the 27-year period since 1980, East Twin Reservoir has remained in a hypereutrophic condition (Plate 127).

6.2.9.2.3 Existing Water Quality Conditions of Runoff Inflows to East Twin Reservoir

Existing water quality conditions in the main tributary inflow to East Twin Reservoir was monitored at site ETNNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.37). Site ETNNF1 was approximately ¼ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 128 summarizes water quality conditions that were monitored at site ETNNF1 under runoff conditions during the period 2002 through 2006.

6.2.9.3 <u>Water Quality in West Twin Reservoir</u>

6.2.9.3.1 Existing Water Quality Conditions (2002 through 2006)

6.2.9.3.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in West Twin Reservoir at site WTNLKND1 from May through September during the period 2002 through 2005 is summarized in Plate 129. Due to low water conditions, the reservoir was not sampled in 2006. A review of these results indicated possible water quality concerns regarding dissolved oxygen, ammonia, nutrients, arsenic, and atrazine.

An appreciable number of dissolved oxygen measurements in West Twin Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plate 129). Given the shallow depth of West Twin Reservoir, the measured dissolved oxygen levels below 5 mg/l may be a water quality standards nonattainment situation.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in West Twin Reservoir in the area near the dam (Plate 129). Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R18 impounded waters include: total phosphorus (139 ug/l), total nitrogen (1,460 ug/l), and chlorophyll *a* (44 ug/l). All three of these criteria were regularly exceeded in West Twin Reservoir (Plate 129).

The chronic arsenic and atrazine criteria for the protection of warmwater aquatic life were exceeded in West Twin Reservoir in the area near the dam (Plate 129). Thirty-three percent of the arsenic and 12 percent of atrazine measurements exceeded the respective chronic criterion.

6.2.9.3.1.2 Summer Thermal Stratification

Existing summer thermal stratification of West Twin Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the 4-year period 2002 through 2005. Depth-profile temperature plots measured during the summer were compiled (Plate 130). The plotted depth-profile temperature measurements indicate the shallowness of the reservoir and the nonoccurrence of summer thermal stratification (Plate 130). Based on the nonoccurrence of significant thermal stratification in the summer, the reservoir appears to be subject to regular mixing in the summer.

6.2.9.3.1.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions in West Twin Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 4-year period 2002

through 2005. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 131). On a few occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 131). Even though West Twin Reservoir is subject to regular mixing, significant vertical gradients in dissolved oxygen concentrations occasionally develop in the reservoir during the summer.

6.2.9.3.1.4 Reservoir Trophic Status

Trophic State Index (TSI) values for West Twin Reservoir were calculated from monitoring data collected during the period 2002 through 2005 at the near-dam ambient monitoring site (i.e., WTNLKND1). Table 6.26 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of West Twin Reservoir is in an advanced hypereutrophic condition.

Table 6.26. Summary of Trophic State Index (TSI) values calculated for West Twin Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	15	86	87	80	97
TSI(TP)	18	75	74	61	89
TSI(Chl)	17	73	73	57	88
TSI(Avg)	18	77	76	71	88

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.9.3.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2005 were determined for West Twin Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., WTNLKND1). Plate 132 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, West Twin Reservoir exhibited decreasing transparency and chlorophyll *a* levels and increasing levels of total phosphorus. Over the 26-year period since 1980, West Twin Reservoir has remained in a hypereutrophic condition (Plate 132).

6.2.9.3.3 Existing Water Quality Conditions of Runoff Inflows to West Twin Reservoir

Existing water quality conditions in the main tributary inflow to West Twin Reservoir was monitored at site WTNNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.37). Site WTNNF1 was approximately ½ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from “base-flow” conditions. Plate 133 summarizes water quality conditions that were monitored at site WTNNF1 under runoff conditions during the period 2002 through 2006.

6.2.10 WAGON TRAIN RESERVOIR

6.2.10.1 Background Information

6.2.10.1.1 Project Overview

The dam forming Wagon Train Reservoir is located on a tributary to the Hickman Branch. The dam was completed on September 24, 1962 and the reservoir reached its initial fill on June 24, 1963. The Wagon Train Reservoir watershed is 15.6 square miles. The watershed was largely agricultural when the dam was built in 1962 and has remained so to the present time.

6.2.10.1.2 Aquatic Habitat Improvement and Water Quality Management Project

A lake renovation project was completed at Wagon Train Reservoir in 2003. The goal of the project was to stabilize eroding shorelines and create fringe wetlands, reduce sediment and nutrient loading to the reservoir, manipulate water levels to promote colonization of aquatic vegetation, set back succession of the rough fish dominated community using rotenone, and restock the reservoir with sport fish. Approximately $2.7 million in Federal, State, and Local funding was spent on the lake renovation project.

Included in the project were the construction of a two-stage sediment/nutrient dike in the upper end of the reservoir and a single stage sediment/nutrient dike at the upper end of the east bay (Figure 6.39). Each dike has an estimated trapping efficiency of about 60 percent. Further, five breakwater jetties totaling 1,175 feet were constructed at strategic locations and now protect 2,350 additional feet of adjacent shoreline from erosive waves. Finally, three islands were constructed just downstream of the large sediment/nutrient dike and have each added about 1,000 feet of shoreline. Collectively, the structures created in this project have added 8,750 feet of additional shoreline, increasing the reservoir's total by 36 percent. The dikes, jetties, and islands have all promoted growth of cattails, bulrushes, arrowhead, and a variety of submersed aquatic plants. This aquatic vegetation is resulting in development of an exceptional fishery. To protect this fishery from unwanted reintroduction of rough fish, the Nebraska Game and Parks Commission has implemented a ban on the possession and use of all baitfish, dead or alive, at the reservoir.

Two-Stage Sediment/Nutrient Dike and Basin

One-Stage Sediment/Nutrient Dike and Basin.

Figure 6.39. Aerial views of sediment/nutrient dikes and basins constructed on Wagon Train Reservoir as part of the lake renovation project (see Figure 6.41 for constructed sediment/nutrient dikes locations on the reservoir).

6.2.10.1.3 Wagon Train Dam Intake Structure

The dam intake at Wagon Train Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 5 feet by 8 feet. The intake structure has four ungated openings – two 30" x 96" openings with a crest elevation at 1292.4 ft-msl and two 12" x 54" openings with a crest elevation at 1287.8. A 36" x 36" gated opening with a crest elevation of 1283.5 ft-msl was constructed into the upstream wall. As part of the recent lake renovation project a "stop-log" structure was attached to the concrete box shaft over the 36" x 36" gated opening. The 36" x 36" gate is permanently left open and pool levels are managed with the external stop-log structure. The purpose of the gate modification is to allow for better management of pool elevations for water quality and fishery management. The gated outlet may also be used to release water for downstream needs.

6.2.10.1.4 Reservoir Storage Zones

Figure 6.40 depicts the current storage zones of Wagon Train Reservoir based on the 1993 survey data, results of the recent lake renovation project, and estimated sedimentation. After accounting for the sediment removed from the reservoir basin as part of the recent lake renovation project, it is estimated that, respectively, 17 and 11 percent of the Sediment Pool Conservation Pool has been lost to sedimentation as of 2006.

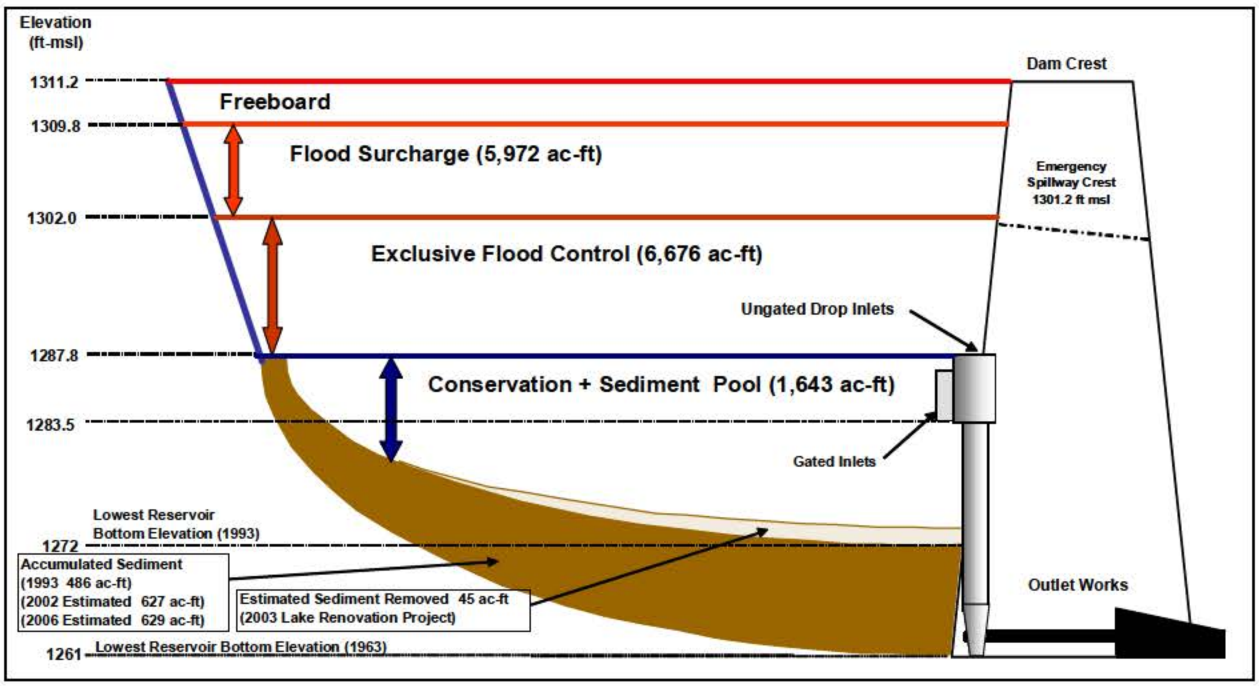

Figure 6.40. Current storage zones of Wagon Train Reservoir based on the 1993 survey data and estimated sedimentation.

6.2.10.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Wagon Train Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Figure 6.41 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006). The inflow runoff site (WAGNF1) was sampled by the NDEQ. The other in-reservoir sites (WAGLKND1 and WAGLKML1) were sampled by the District. The near-dam location (WAGLKND1) has been continuously monitored since 1980.

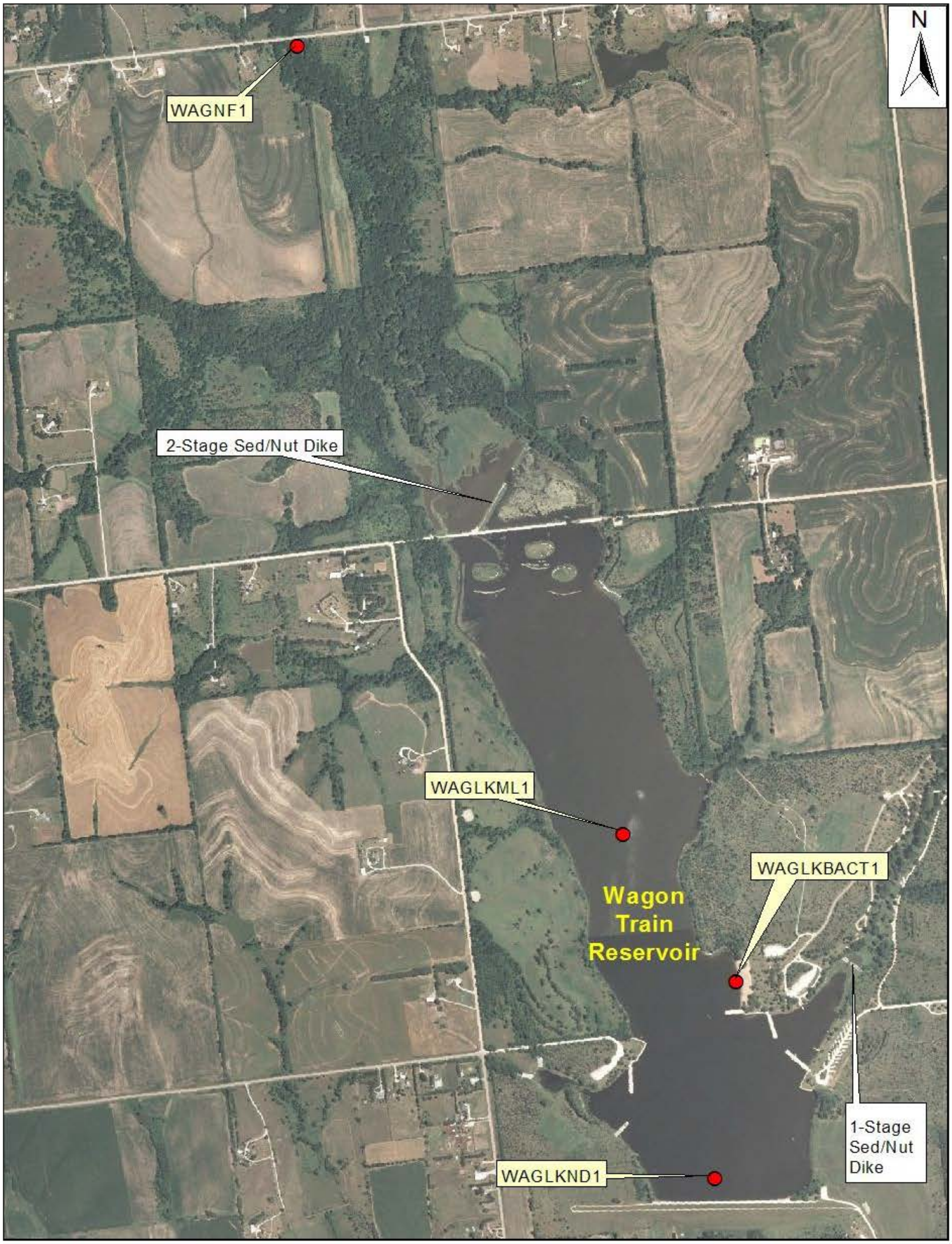

Figure 6.41. Location of sites where water quality monitoring was conducted at Wagon Reservoir during the period 2002 through 2006.

6.2.10.2 Water Quality in Wagon Train Reservoir

6.2.10.2.1 Existing Water Quality Conditions (2002 through 2006)

6.2.10.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Wagon Train Reservoir at sites WAGLKND1 and WAGLKML1 from May through September during the period 2003 through 2006 are summarized, respectively, in Plates 134 and 135. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, ammonia, nutrients, and arsenic.

An appreciable number of dissolved oxygen measurements throughout Wagon Train Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life (Plates 134 and 135). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in Wagon Train Reservoir, and the measured dissolved oxygen levels below 5 mg/l may not be a water quality standards nonattainment situation.

A few (<5%) pH readings measured throughout Wagon Train Reservoir were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life (Plates 134 and 135). The magnitude and number of pH criterion exceedences seemingly do not indicate a significant water quality concern at this time. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Wagon Train Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

Nutrient criteria defined in Nebraska's water quality standards for R13 impounded waters include: total phosphorus (143 ug/l), total nitrogen (1,540 ug/l), and chlorophyll *a* (16 ug/l). All three of these criteria were regularly exceeded throughout the reservoir.

The chronic arsenic criterion for the protection of warmwater aquatic life was exceeded in Wagon Train Reservoir in the area near the dam (Plate 134). Seventy-five percent of the arsenic measurements exceeded the chronic criterion.

6.2.10.2.1.2 Summer Thermal Stratification

6.2.10.2.1.2.1 <u>2006 Monthly Longitudinal Temperature Contour Plots</u>

Summer thermal stratification of Wagon Train Reservoir during 2006 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, and September at sites WAGLKND1 and WAGLKML1 (Plate 136). Plate 136 indicates that some thermal stratification occurred in Wagon Train Reservoir during the summer. The greatest monitored difference between surface and bottom water temperatures was 3° to 4°C (Plate 136).

6.2.10.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Wagon Train Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 4 years. Depth-profile temperature plots measured during the summer were compiled (Plate 137). The plotted depth-profile temperature measurements indicate that the reservoir occasionally exhibits significant summer thermal stratification (Plate 137). Based on the occasional occurrence of significant thermal stratification in the summer, Wagon Train Reservoir appears to be polymixic.

6.2.10.2.1.3 Summer Dissolved Oxygen Conditions

6.2.10.2.1.3.1 2006 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Wagon Train Reservoir based on depth-profile measurements taken in June, July, and September 2006 at sites WAGLKND1 and WAGLKML1 (Plate 138). Dissolved oxygen concentrations < 5 mg/l were monitored in the lower depths of the reservoir in all three months (Plate 138). Anoxic conditions (i.e., < 2 mg/l dissolved oxygen) were monitored in a small area along the bottom of the middle reaches of the reservoir in July (Plate 138). During the summer of 2006, dissolved oxygen concentrations in Wagon Train Reservoir exhibited significant vertical variation (Plate 138).

6.2.10.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Wagon Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 4 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 139). On a several occasions there was a significant vertical gradient in summer dissolved oxygen levels (Plate 139). Even though Wagon Train Reservoir appears to be polymixic, significant vertical variation in dissolved oxygen occurs during the summer.

6.2.10.2.1.4 Water Clarity

6.2.10.2.1.4.1 Secchi Transparency

Figure 6.42 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., WAGLKND1 and WAGLKML1) during the 4-year period 2003 through 2006 (note: the monitoring sites are oriented in an upstream to downstream direction). Transparencies measured at the two sites were similar (Figure 6.42).

6.2.10.2.1.4.2 Turbidity

Monthly (i.e., June, July, and September) longitudinal turbidity contour plots were prepared for Wagon Train Reservoir from the depth-profile turbidity measurements taken at sites WAGLKND1 and WAGLKML1 during 2006 (Plate 140). As seen in Plate 140, Wagon Train Reservoir did not exhibit much vertical and longitudinal variability in turbidity.

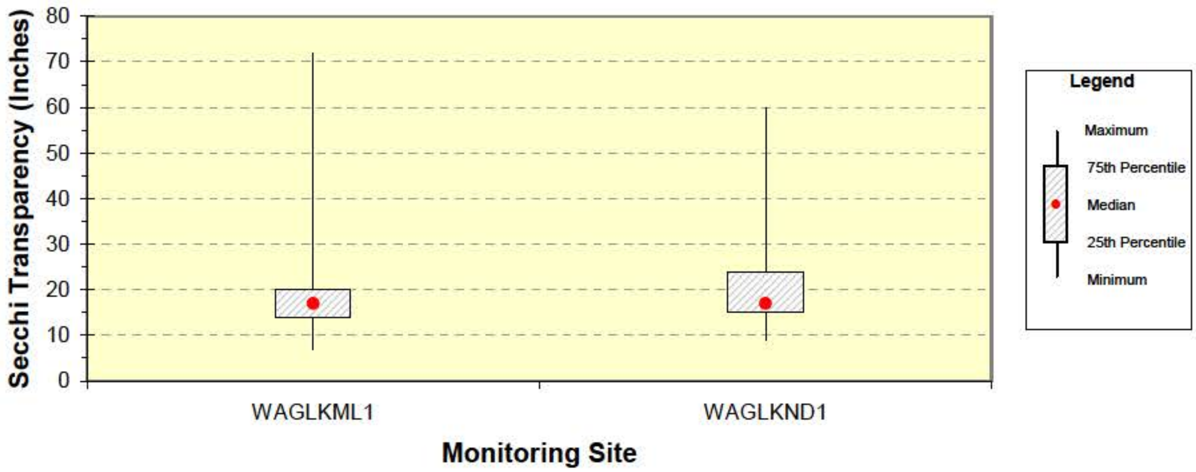

Figure 6.42. Box plot of Secchi depth transparencies measured in Wagon Train Reservoir during the period 2003 through 2006. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.).

6.2.10.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Wagon Train Reservoir during the summer over the past 4 years in the near-dam, deepwater area (i.e. site WAGLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the reservoir surface, and near-bottom samples were defined as samples collected within 1 meter of the reservoir bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, and orthophosphorus (Plate 141). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen, varied significantly between the surface and the bottom (Plate 141). Measured dissolved oxygen concentrations were significantly lower near the reservoir bottom.

6.2.10.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Wagon Train Reservoir were calculated from monitoring data collected during the period 2003 through 2006 at the near-dam ambient monitoring site (i.e., WAGLKND1). Table 6.27 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Wagon Train Reservoir is in a hypereutrophic condition.

6.2.10.2.1.7 Monitoring at Swimming Beaches

A designated swimming beach is located on Wagon Train Reservoir. Bacteria (i.e., *E. coli*) and the cyanobacterial toxin microcystins were monitored at the swimming beach on the reservoir at site WAGLKBACT1 by the NDEQ (Figure 6.41). Bacteria were monitored from May through September over the 4-year period 2003 through 2006, and microcystins was monitored from May through September during 2005 and 2006.

Table 6.27. Summary of Trophic State Index (TSI) values calculated for Wagon Train Reservoir for the 5-year period 2002 through 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	20	70	72	54	81
TSI(TP)	20	74	75	63	80
TSI(Chl)	19	64	65	40	85
TSI(Avg)	20	70	69	57	79

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.
Note: See Section 4.1.3 for discussion of TSI calculation.

6.2.10.2.1.7.1 <u>Bacteria Monitoring</u>

Table 6.28 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following *E. coli* bacteria criteria for support of "full-body contact" recreation:

> *E. coli* bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation is supported in Wagon Train Reservoir during the May through September recreational season. The individual criterion was extended by 8% of the *E. coli* samples, and the geomean criterion was not exceeded by any of the 68 calculated geomeans during the 5-year period 2002 through 2006.

Table 6.28. Summary of weekly (May through September) *E. coli* bacteria samples collected at Wagon Train Reservoir (i.e., site WAGLKBACT1) during the 4-year period 2003 through 2006.

E. coli **– Individual Samples**		***E. coli*** **– Geomeans**	
Number of Samples	84	Number of Geomeans	68
Mean (cfu/100ml)	97	Average	20
Median (cfu/100ml)	9	Median	15
Minimum (cfu/100ml)	1	Minimum	2
Maximum (cfu/100ml)	3,076	Maximum	95
Percent of samples exceeding 235/100ml	8%	Number of Geomeans exceeding 126/100ml	0%

6.2.10.2.1.7.2 <u>Microcystins Monitoring</u>

Table 6.29 summarizes the microcystins monitoring conducted at the Wagon Train Reservoir swimming beach in 2005 and 2006. These results were compared to the 20 ug/l criterion identified by the NDEQ for issuing health advisories and the posting of swimming beaches. None of the collected samples exceeded the criterion. The monitored levels of microcystins seemingly indicate that a cyanobacterial toxin concern does not exist at Wagon Train Reservoir.

Table 6.29. Summary of weekly (May through September) microcystins samples collected at the Wagon Train Reservoir swimming beach (i.e., site WAGLKBACT1) during 2005 and 2006.

Summary Statistic	Swimming Beach (Site WAGLKBACT1)
Number of Samples	43
Minimum (ug/l)	0
25^{th} percentile (ug/l)	0
Median (ug/l)	<0.1
75^{th} Percentile (ug/l)	0.1
Maximum (ug/l)	0.9
Percent of samples exceeding 20 ug/l	0%

6.2.10.2.2 Water Quality Trends (1980 through 2006)

Water quality trends from 1980 to 2006 were determined for Wagon Train Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., WAGLKND1). Plate 142 displays a scatter-plot of the collected data for the four parameters and a monotonic linear regression lines for the periods 1980 through 1998 and 2003 through 2006. The data gap of 1998 through 2002 is the period when the lake renovation project was implemented at Wagon Train Reservoir. When 5 years of post-project data has been collected, analyses for step trend assessment will be pursued to test for water quality changes from "pre-project" conditions.

6.2.10.2.3 Existing Water Quality Conditions of Runoff Inflows to Wagon Train Reservoir

Existing water quality conditions in the main tributary inflow to Wagon Train Reservoir was monitored at site WAGNF1 by the NDEQ under runoff conditions during the period of April through September (Figure 6.41). Site WAGNF1 was approximately 1 mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plate 143 summarizes water quality conditions that were monitored at site WAGNF1 under runoff conditions during the period 2002 through 2006.

6.2.11 YANKEE HILL RESERVOIR

6.2.11.1 Background Information

6.2.11.1.1 Project Overview

The dam forming Yankee Hill Reservoir is located on the Cardwell Branch. The dam was completed on August 27, 1963 and the reservoir reached its initial fill in May 1965. The Yankee Hill Reservoir watershed is 9.7 square miles. The watershed was largely agricultural when the dam was built in 1963 and has remained so to the present time.

6.2.11.1.2 Aquatic Habitat Improvement and Water Quality Management Project

A lake renovation project was started at Yankee Hill Reservoir in 1999 and completed in 2005. To facilitate the project, the reservoir was drawn down in 1998 and is currently refilling. The goal of the

project was to reduce the threat if winter fish kills, create more open water habitat for fish, stabilize shorelines and create fringe wetlands, reduce sediment and nutrient loading into the reservoir, manipulate water levels to promote fish production, and set back succession by restructuring the rough fish dominated fishery. Approximately $1.9 million in Federal, State, and Local funding was spent on the lake renovation project.

Included in the project were three sediment/nutrient dikes, three offshore breakwaters, three islands, five jetties, six hardpoints, seven underwater islands, modification of the outlet structure, a new boat ramp and parking lot, reservoir basin excavation, and fish renovation and restocking. Reservoir basin excavation included the excavation and disposal of 349,800 cubic yards of material beyond the reservoir's flood pool and the relocation of 95,000 cubic yards as compact fill for jetties, offshore breakwaters and sediment dikes with the reservoir basin. Material disposed outside the flood pool has enlarged the reservoir's volume by 216.7 ac-ft, a 19 percent increase, and increased the mean depth of the reservoir from 6.4 to 7.1 feet. The three sediment dikes are expected to reduce sediment loads by 50 percent annually. Collectively, the jetties, breakwaters and islands have added 16,135 feet of productive shoreline to the reservoir, a 79 percent increase. Fish attractors in the form of cedar trees have also been added to the reservoir. The reservoir is currently refilling and fish stocking will begin when the reservoir has filled sufficiently to support fish.

6.2.11.1.3 Yankee Hill Dam Intake Structure

The dam intake at Yankee Hill is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 3.5 feet by 5.25 feet. The intake structure has four ungated openings – two 18” x 63” openings with a crest elevation at 1250.0 ft-msl and two 12” x 30” openings with a crest elevation at 1244.9 ft-msl. A 36” x 36” gated opening with a crest elevation of 1237.0 ft-msl was constructed into the upstream wall. As part of the recent lake renovation project a “stop-log” structure was attached to the concrete box shaft over the 36” x 36” gated opening. The 36” x 36” gate is permanently left open and pool levels are managed with the external stop-log structure. The purpose of the gate modification is to allow for better management of pool elevations for water quality and fishery management. The gated outlet may also be used to release water for downstream needs.

6.2.11.1.4 Reservoir Storage Zones

Figure 6.43 depicts the current storage zones of Yankee Hill Reservoir based on the 1994 survey data, results of the recent lake renovation project, and estimated sedimentation. After accounting for the sediment removed from the reservoir basin as part of the recent lake renovation project, it is estimated that, respectively, 12 and 8 percent of the Sediment and Conservation Pools have been lost to sedimentation as of 2006.

6.2.11.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Yankee Hill Reservoir since the late 1970’s. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. As mentioned, a lake renovation project was implemented at Yankee Hill reservoir from 1999 through 2005. During this period the reservoir was drawn down to facilitate construction activities, and in-reservoir water quality monitoring by the District was discontinued. However, runoff monitoring by the NDEQ on the two main tributary inflows to the reservoir continued through this period. The reservoir is in the process of refilling and in-reservoir water quality monitoring will be restarted by the District in 2007. Figure 6.44 shows the location of the sites that have been monitored for water quality during the past 5 years (i.e., 2002 through 2006) and will be monitored in the future. The near-dam location (YANLKND1) was continuously monitored from 1980 through 1998.

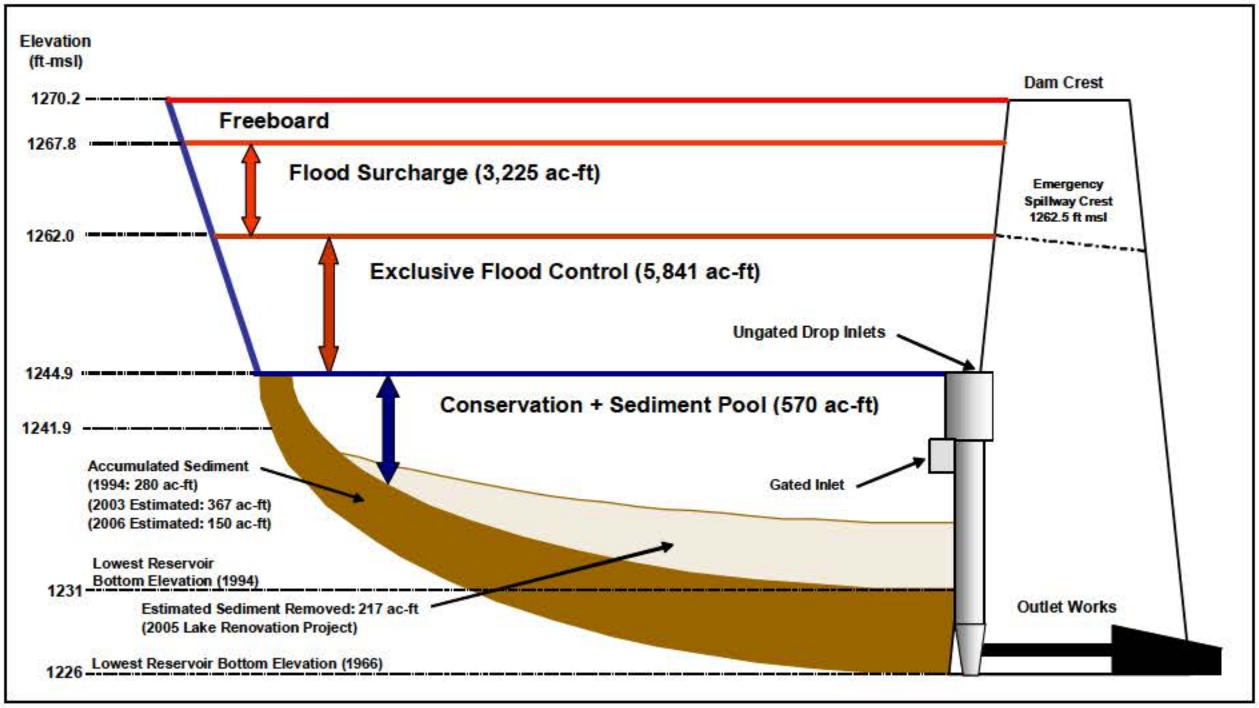

Figure 6.43. Current storage zones of Yankee Hill Reservoir based on the 1994 survey data and estimated sedimentation.

6.2.11.2 Water Quality in Yankee Hill Reservoir

6.2.11.2.1 Existing Water Quality Conditions (2002 through 2006)

No water quality monitoring in Yankee Hill Reservoir was conducted during the period 2002 through 2006 due to reservoir drawdown and implementation of the lake renovation project.

6.2.11.2.2 Water Quality Trends (1980 through 1997)

Water quality trends from 1980 to 1998 were determined for Yankee Hill Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., YANLKND1). Plate 144 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Wagon Train Reservoir exhibited decreasing transparency and chlorophyll *a* levels and increasing levels of total phosphorus. Over the 19-year period of 1980 through 1998, Yankee Hill Reservoir was in a eutrophic to hypereutrophic condition (Plate 144).

6.2.11.2.3 Existing Water Quality Conditions of Runoff Inflows to Yankee Hill Reservoir

Existing water quality conditions in the main tributary inflows to Yankee Hill Reservoir were monitored by the NDEQ under runoff conditions, during the period of April through September, at two sites YANNFWST1 and YANNFSTH1 (Figure 6.44). Both sites were about ¼ mile upstream from the reservoir. Runoff conditions were considered to be a 1-inch rainfall event or a 6-inch or more rise in stream stage from "base-flow" conditions. Plates 145 and 146, respectively, summarize water quality conditions that were monitored at sites YANNFWST1 and YANNFSTH1 under runoff conditions during the period 2002 through 2006.

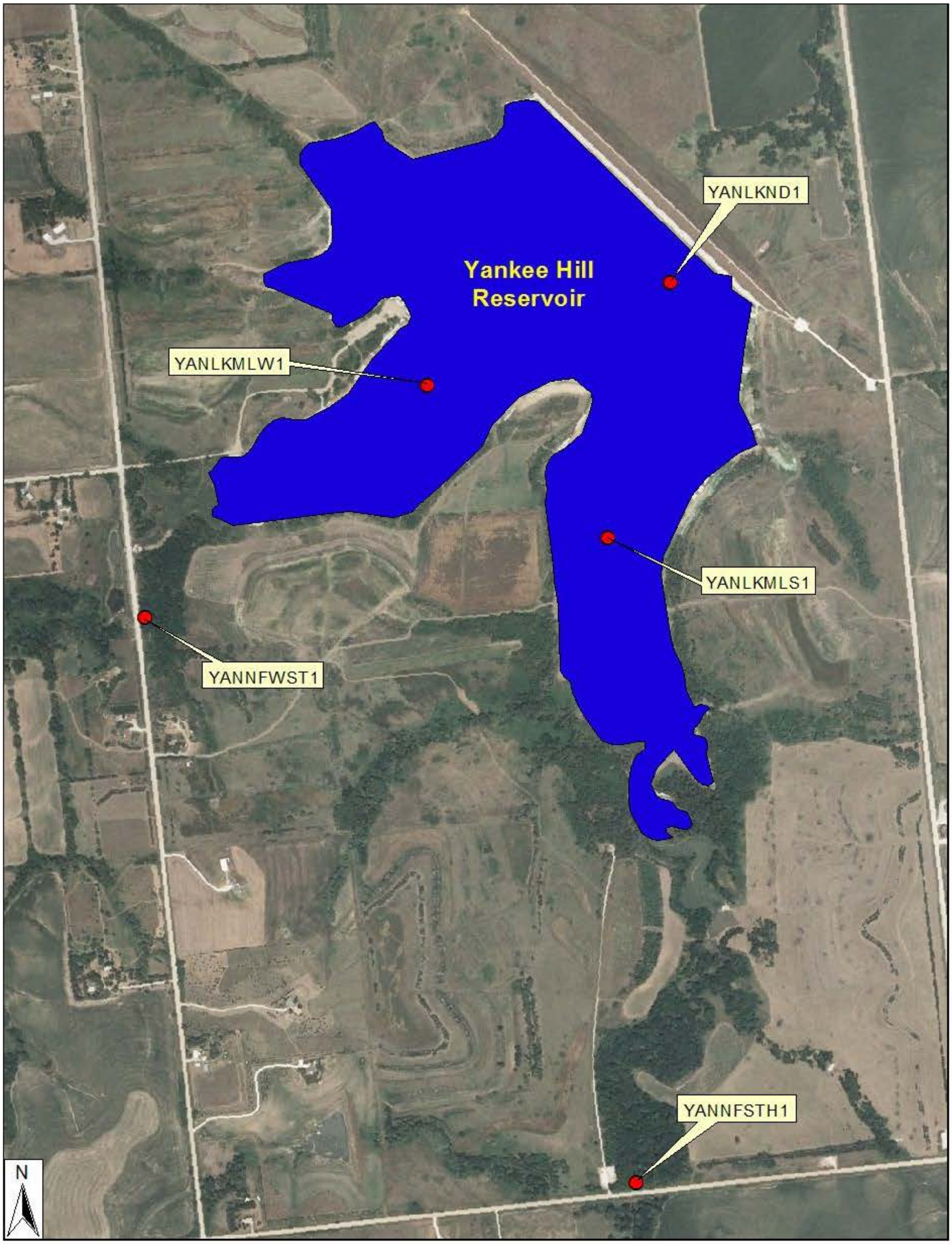

Figure 6.44. Location of sites where water quality monitoring was conducted at Yankee Hill during the period 2002 through 2006, and will be monitored in the future**.**

6.3 SUMMARY OF WATER QUALITY CONDITIONS MONITORED AT THE NEBRASKA TRIBUTARY PROJECTS

6.3.1 SEDIMENTATION

Estimated sedimentation at the Papillion and Salt Creek tributary reservoirs, as of 2006, is presented in Figure 6.45. Figure 6.45 gives the estimated volume loss of the Conservation plus Sediment Pool volume from "as-built" conditions. Some of the reservoirs do not have a Conservation Pool allocated. In all cases, the pool volume loss represented is the estimated loss of the pool volume below the ungated drop inlet crest elevation.

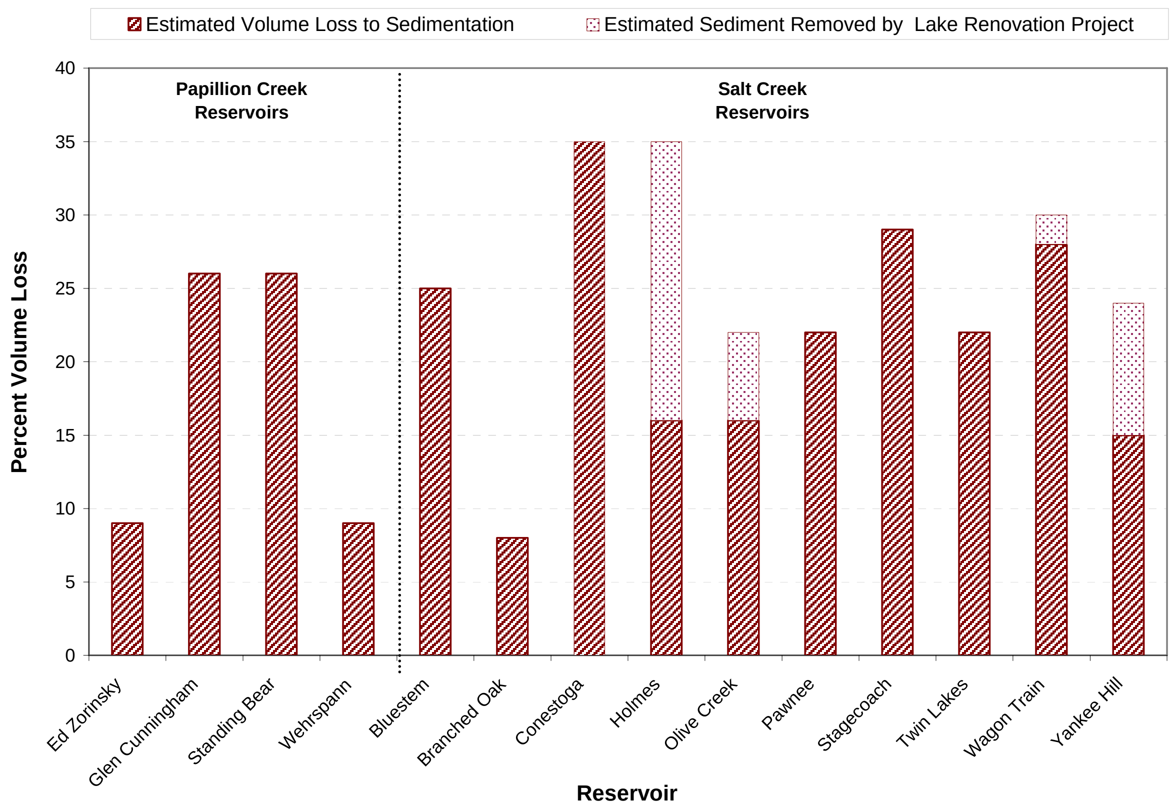

Figure 6.45. Estimated volume loss of the Conservation plus Sediment Pool volume (i.e., pool volume below the ungated drop inlet crest elevation) from "as-built" conditions as of 2006.

6.3.2 WATER QUALITY STANDARDS EXCEEDENCES

Table 6.30 presents a summary of the exceedences of State water quality standards that occurred at the Papillion and Salt Creek tributary reservoirs based on water quality monitoring conducted over the 5-year period of 2002 through 2006. Except for *E. coli* and microcystins, the percentages presented in Table 6.30 represent the number of exceedences that occurred at the near-dam, deepwater ambient monitoring site. For *E. coli* and microcystins, samples were collected at designated swimming beaches or areas of high recreational use. Results for dissolved oxygen and pH are for water column profile measurements. Results for chlorophyll *a*, atrazine, lead, cadmium, selenium, *E. coli*, and microcystins are for "grab samples" collected near the reservoir surface. Results for total nitrogen, total ammonia, and total phosphorus are for "grab samples" collected at near-surface and near-bottom depths.

Table 6.30. Percent exceedences of water quality standards criteria for all samples collected at near-dam, deepwater monitoring sites during the period of 2002 through 2006. (Note: *E. coli* and microcystins samples were collected at designated swimming beaches or areas of high recreational use.)

	Dissolved Oxygen (<5 mg/l)	**pH** (> 9 SU)	**Total Ammonia** (Variable)[1]	**Total Nitrogen** (>1.54 mg/l)[2] (>1.46 mg/l)[2]	**Total Phosphorus** (>143 ug/l)[3] (>139 ug/l)[3]	**Chlorophyll *a*** (>16 ug/l)[4] (>44 ug/l)[4]	**Atrazine** (>12 ug/l)	**Arsenic** (>16.7 ug/l)	**Lead** (Variable)[5]	**Cadmium** (Variable)[5]	**Selenium** (>5 ug/l)	***E. coli*[6]** (>126/100ml)[7] (>235/100ml)[8]	**Microcystins[6]** (>20 ug/l)
Papillion Creek Reservoirs													
Ed Zorinsky	21%	3%	6%	9%	12%	12%	0%	0%	0%	25%	0%	-----	-----
Glenn Cunningham	33%	6%	0%	32%	32%	29%	0%	0%	0%	0%	0%	4% 6%	-----
Standing Bear	28%	2%	3%	8%	12%	62%	0%	0%	0%	0%	0%	-----	-----
Wehrspann	20%	2%	11%	0%	31%	74%	0%	0%	0%	0%	0%	-----	-----
Salt Creek Reservoirs													
Bluestem	6%	0%	0%	52%	90%	33%	0%	0%	0%	0%	0%	26% 21%	2%
Branched Oak	6%	1%	3%	0%	12%	59%	0%	0%	0%	0%	0%	6% 11%	0%
Conestoga	10%	10%	9%	59%	60%	67%	0%	0%	0%	0%	0%	0% 2%	21%
East Twin	14%	1%	6%	37%	12%	55%	0%	0%	0%	0%	0%	-----	-----
Holmes	26%	10%	0%	20%	10%	0%	0%	0%	0%	0%	0%	0% 24%	0%
Olive Creek	15%	39%	13%	76%	84%	42%	5%	75%	0%	0%	0%	-----	-----
Pawnee	17%	4%	11%	40%	36%	43%	0%	20%	0%	0%	20%	2% 7%	40%
Stagecoach	25%	3%	0%	23%	66%	39%	8%	0%	20%	0%	0%	-----	-----
Wagon Train	25%	3%	6%	28%	80%	33%	0%	75%	0%	0%	0%	0% 8%	0%
West Twin	14%	2%	13%	81%	96%	29%	12%	33%	0%	0%	0%	-----	-----
Yankee Hill	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

(1) Total ammonia criteria are pH and temperature dependent. Percent exceedence based on median pH and temperature conditions and may not represent conditions when total ammonia was measured.
(2) Total nitrogen criteria defined for R13 and R18 categorized lakes are, respectively, 1.54 and 1.46 mg/l.
(3) Total phosphorus criteria defined for R13 and R18 categorized lakes are, respectively, 143 and 139 ug/l.
(4) Chlorophyll *a* criteria defined for R13 and R18 categorized lakes are, respectively, 16 and 44 ug/l.
(5) Certain metals criteria are hardness dependent. Percent exceedence based on median hardness conditions and may not represent conditions at time of metals' measurement.
(6) Samples collected at designated swimming beaches or areas of heavy recreational use.
(7) Criterion is for geometric mean of 5 samples collected within a 30-day period.
(8) Criterion is for an individual observation.

6.3.3 WATER CLARITY

Figure 6.46 presents a box plot of Secchi depths recorded at the Papillion and Salt Creek tributary reservoirs over the 5-year period of 2002 through 2006. Bluestem and Olive Creek Reservoirs had median Secchi depths of less than 10 inches, while Ed Zorinsky, Holmes, and Pawnee Reservoirs had median Secchi depths greater than 30 inches.

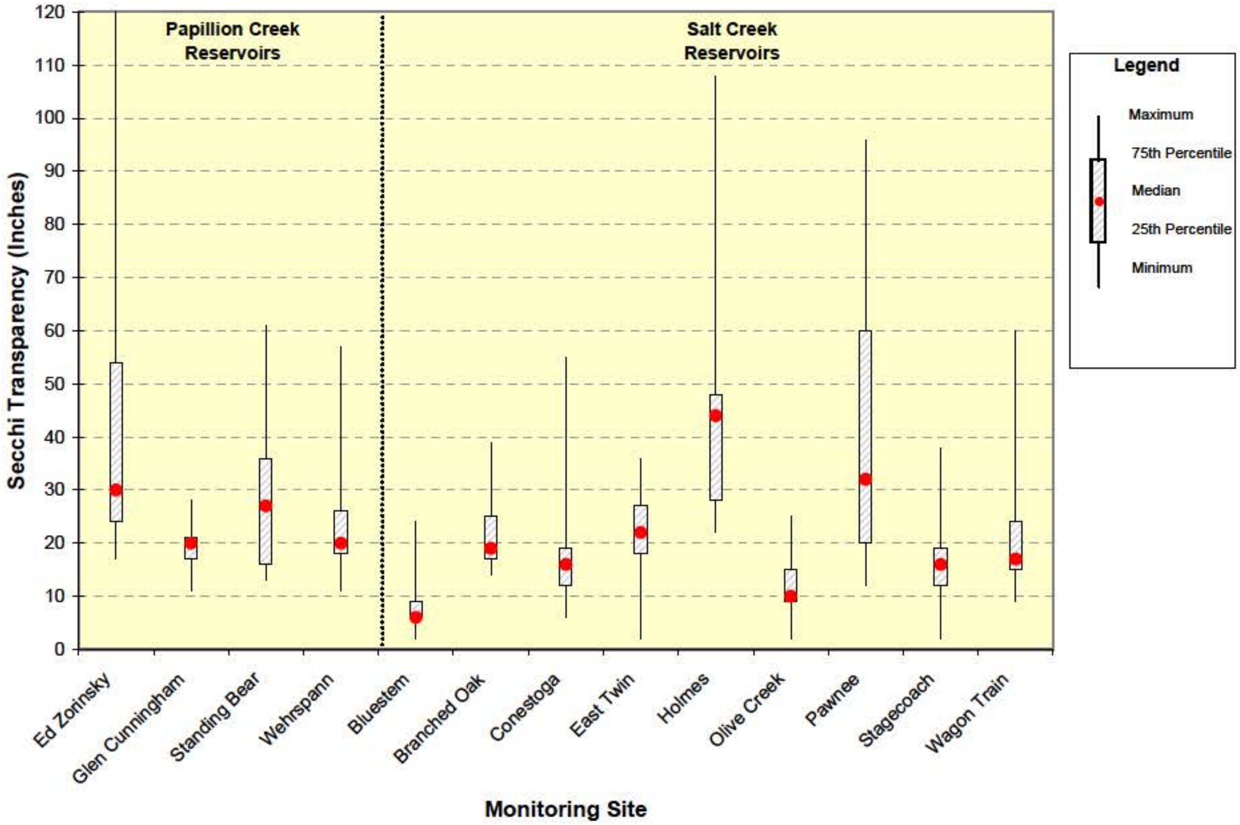

Figure 6.46. Box plot of Secchi depths measured at the Papillion and Salt Creek tributary reservoirs over the 5-year period of 2002 through 2006.

6.3.4 TROPHIC CONDITION

Figure 6.47 presents a box plot of Trophic State Index (TSI) values calculated for the Papillion and Salt Creek tributary reservoirs. The TSI values are based of Secchi depth, total phosphorus, and chlorophyll *a* levels monitored at the reservoirs over the 5-year period of 2002 through 2006. TSI values were calculated as described by Carlson (1977). Median TSI values determined for four reservoirs (i.e., Ed Zorinsky, Standing Bear, Holmes and Olive Creek) indicated that they were in a eutrophic condition. The other nine reservoirs (i.e., Glenn Cunningham, Wehrspann, Bluestem, Branched Oak, Conestoga, East Twin, Pawnee, Stagecoach, and Wagon Train) where TSI values were determined indicated the reservoirs were in a Hypereutrophic condition.

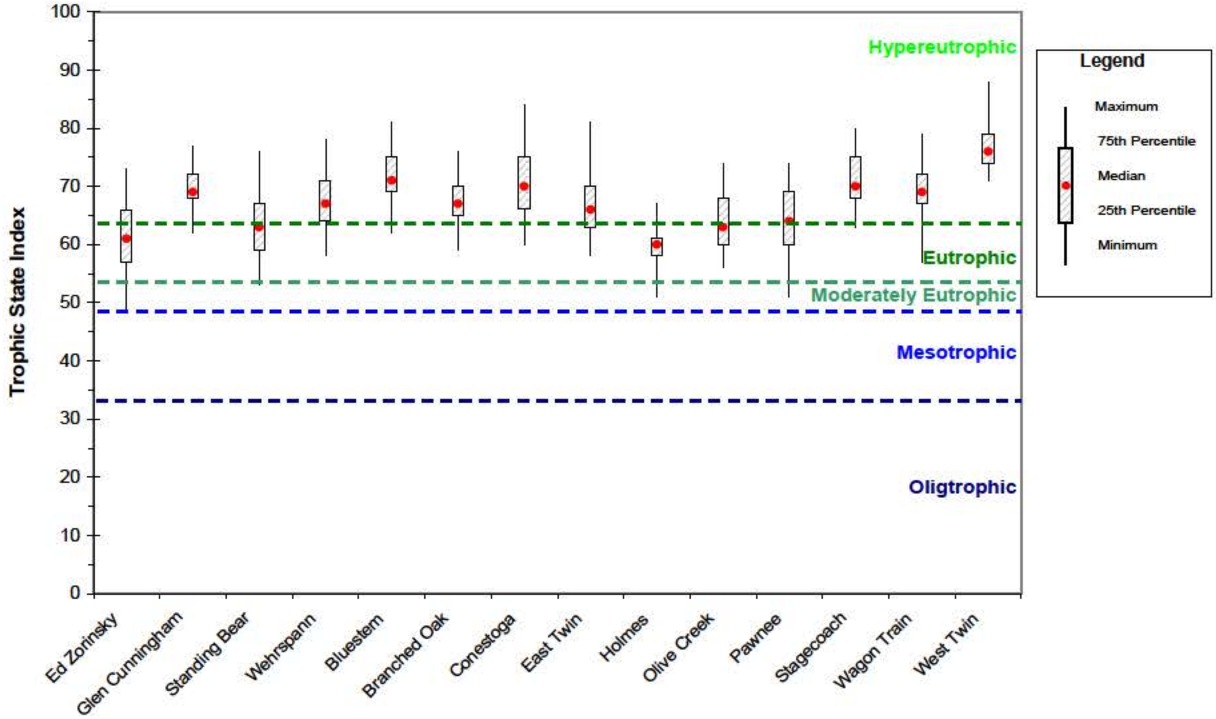

Figure 6.47. Box plot of Trophic State Index values calculated at the Papillion and Salt Creek tributary reservoirs based on Secchi depth, total phosphorus, and chlorophyll *a* measurements taken over the 5-year period of 2002 through 2006.

6.3.5 WATER QUALITY TRENDS

Water quality trends (i.e., linear regression) observed for transparency (i.e., Secchi Depth), total phosphorus, chlorophyll *a*, and trophic state index (TSI) for the period of 1980 through 2006 at the Papillion and Salt Creek Reservoirs are presented in Table 6.31. Based on water quality monitoring conducted at the near-dam, deepwater ambient monitoring site.

Table 6.31. Observable trends in transparency, total phosphorus, chlorophyll *a*, and trophic state index (TSI) based on monitoring conducted over the period of 1980 through 2006.

Reservoir	Transparency	Total Phosphorus	Chlorophyll *a*	TSI
Papillion Creek Reservoirs:				
Ed Zorinsky	Decreasing	None	Increasing	Increasing
Glenn Cunningham	Decreasing	Increasing	None	Increasing
Standing Bear	Decreasing	None	None	None
Wehrspann	Decreasing	Decreasing	Increasing	Increasing
Salt Creek Reservoirs:				
Bluestem	Decreasing	Increasing	None	None
Branched Oak	Decreasing	Increasing	Increasing	Increasing
Conestoga	None	Increasing	Increasing	Increasing
East Twin	None	None	None	None
Pawnee	Increasing	Increasing	None	None
Stagecoach	Decreasing	Increasing	Decreasing	Increasing
West Twin	Decreasing	Increasing	Decreasing	None

Note: Trends are not given for Holmes, Olive Creek, Wagon Train, and Yankee Hill Reservoirs. Lake renovations projects have recently been completed at these reservoirs.

7 NORTH DAKOTA TRIBUTARY PROJECTS

Two District tributary reservoir projects are located in North Dakota: Bowman-Haley and Pipestem. Bowman-Haley Reservoir is located in southwest North Dakota along the South Dakota border (Figure 1.1). Pipestem Reservoir is located in southeast North Dakota (Figure 1.1). Table 7.1 gives selected engineering data for the Bowman-Haley and Pipestem Projects.

7.1 BOWMAN-HALEY RESERVOIR

7.1.1 Background Information

7.1.1.1 Project Overview

The dam forming Bowman-Haley Reservoir is located on the North Fork of the Grand River, 6 miles west of Haley, North Dakota. The dam was completed in August 1966 and the reservoir reached its initial fill in March 1969. The Bowman-Haley Reservoir watershed is 446 square miles. The watershed was largely agricultural and rangeland when the dam was built in 1966 and has remained so to the present time. The authorized project purposes of Bowman-Haley Reservoir are flood control, recreation, fish and wildlife, water quality, and water supply.

7.1.1.2 Bowman-Haley Dam Intake Structure

The intake structure at Bowman-Haley Dam is a shaft with a fixed weir for automatic release of water when the reservoir level rises above elevation 2754.8 ft-msl. The ungated glory hole has a crest elevation of 2754.8 ft-msl. Provision for low-level release of water is by means of a 30-inch gated pipe located in the dry well part of the intake. A 30-inch diameter slide gate is provided in the wet well as an emergency closure of the 30-inch pipe. The invert elevation for the low-level gate is 2740.0 ft-msl.

7.1.1.3 Reservoir Storage Zones

Two storage zones are provided in the reservoir, a multiple-purpose zone and a flood control zone. The multipurpose zone of 18,765 ac-ft includes storage for water supply, fish and wildlife, and recreation. In addition this zone contains space for storing an estimated 100 years of sediment deposition. The water supply storage was developed for maximum possible yield form the contributing drainage areas. Figure 7.1 depicts the current storage zones of Bowman-Haley Reservoir based on the 1984 survey data and estimated sedimentation. It is estimated that 12 percent of the Multipurpose Pool has been lost to sedimentation as of 2006.

7.1.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

The State of North Dakota has designated Bowman-Haley Reservoir as a Class 3 lake in the State's water quality standards. The beneficial uses designated for Class I streams are also applicable to all classified lakes in North Dakota. As such, the beneficial uses designated for Bowman-Haley Reservoir are: primary contact recreation, warmwater fishery, wildlife, and agricultural water supply. Water quality is also to be suitable for municipal or domestic use after appropriate treatment. The reservoir is not directly used as a municipal or domestic water supply. Pursuant to the Federal CWA, the State of North Dakota has not listed Bowman-Haley Reservoir on the State's Section 303(d) list. The State of North Dakota has issued a statewide fish consumption advisory for mercury. As such, the advisory applies to Bowman-Haley Reservoir.

Table 7.1. Summary of selected engineering data for the Bowman-Haley and Pipestem Projects.

	Bowman-Haley Reservoir	Pipestem Reservoir
General		
Dammed Stream	North Fork Grand River	Pipestem Creek
Drainage Area	446 sq mi	594 sq mi
Reservoir Length[(1)]	2 5 miles	5 5 miles
Multipurpose Pool Elevation (Top)	2754 8 ft-msl	1442 4 ft-msl
Date of Dam Closure	August 1966	July 1973
Date of Initial Fill[(2)]	March 1969	May 1974
"As-Built" Conditions[(3)]	(Project Operation and Maintenance Manual)	(1973 Survey Data)
Lowest Reservoir Bottom Elevation	2715 ft-msl	1407 ft-msl
Surface Area at top of Multipurpose Pool	1750 ac	834
Capacity to top of Multipurpose Pool	24,060 ac-ft	9,023 ac-ft
Mean Depth at top of Multipurpose Pool[(4)]	13 7 ft	10 8 ft
Latest Surveyed Conditions	(1984 Survey Data)	(1990 Survey Data)
Lowest Reservoir Bottom Elevation	2721 ft-msl	1414 ft-msl
Surface Area at top of Multipurpose Pool	1750 ac	835 ac
Capacity of Multipurpose Pool	18,765	8,860 ac-ft
Mean Depth at top of Multipurpose Pool[(4)]	10 7	10 6 ft
Sediment Deposition in Multipurpose Pool		
Historic Sediment Deposition[(5)]	Unknown[(9)]	163 ac-ft
Annual Sedimentation Rate[(6)]	Unknown[(9)]	1973-1990 9 1 ac-ft/yr
Current Estimated Sediment Deposition[(7)]	Unknown[(9)]	309 ac-ft
Current capacity of Multipurpose Pool[(8)]	Unknown[(9)]	8,714 ac-ft
Percent of "As-Built" Multipurpose Pool capacity lost to current estimated sediment deposition	Unknown[(9)]	3%
Operational Details – Historic	(1970 – 2006)	(1975 – 2006)
Maximum Recorded Pool Elevation	2762 7 ft-msl 28-Mar-78	1487 0 ft-msl 10-May-97
Minimum Recorded Pool Elevation	2747 6 ft-msl 12-Jun-92	1439 7 ft-msl 18-Feb-93
Maximum Recorded Daily Inflow	5,310 cfs 27-Mar-78	4,374 cfs 16-Jul-93
Maximum Recorded Daily Outflow	2,390 cfs 28-Mar-78	797 cfs 16-Jun-01
Average Annual Pool Elevation	2753 2 ft-msl	1447 2 ft-msl
Average Annual Inflow	20,976 ac-ft	44,776 ac-ft
Average Annual Outflow	16,066 ac-ft	41,157 ac-ft
Estimated Retention Time[(10)]	1 17 Years	0 21 Years
Operational Details – Current[(11)]		
Maximum Recorded Pool Elevation	2754 7 ft-msl 26-Apr-06	1443 3 ft-msl 13-Mar-06
Minimum Recorded Pool Elevation	2750 9 ft-msl 2-Oct-05	1442 1 ft-msl 11-Sep-06
Maximum Recorded Daily Inflow	671 cfs 24-Apr-06	126 cfs 11-Mar-06
Maximum Recorded Daily Outflow	133 cfs 26-Apr-06	104 cfs 7-Apr-06
Total Inflow (% of Normal)	14,696 ac-ft (70%)	11,840 ac-ft (27%)
Total Outflow (% of Normal)	10,046 ac-ft (64%)	10,116 ac-ft (25%)
Outlet Works		
Ungated Outlets	Glory Hole 2754 8 ft-msl	Drop Inlet 1442 5 ft-msl
Gated Outlets (Mid-depth)		2) 4'x 7' Service Gates
Gated Outlets (Low-level)	1) 30" Dia Gate Valve 2740 0 ft-msl	1) 3'x 3' Slide Gate 1433 0 ft-msl 1) 3' Dia Gate Valve 1415 0 ft-msl

(1) Reservoir length at top of conservation pool
(2) First occurrence of reservoir pool elevation to top of multipurpose pool elevation
(3) "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
(4) Mean Depth = Volume ÷ Surface Area
(5) Difference in reservoir storage capacity to top of Multipurpose Pool between "as-built" and latest survey
(6) Annualized rate based on historic accumulated sediment
(7) Current accumulated sediment estimated from historic annual sedimentation rate
(8) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
(9) Unable to caluculate accumulated sediment and sediment deposition rates because only one bathymetric survey conducted on Bowman-Haley Reservoir
(10) Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
(11) Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

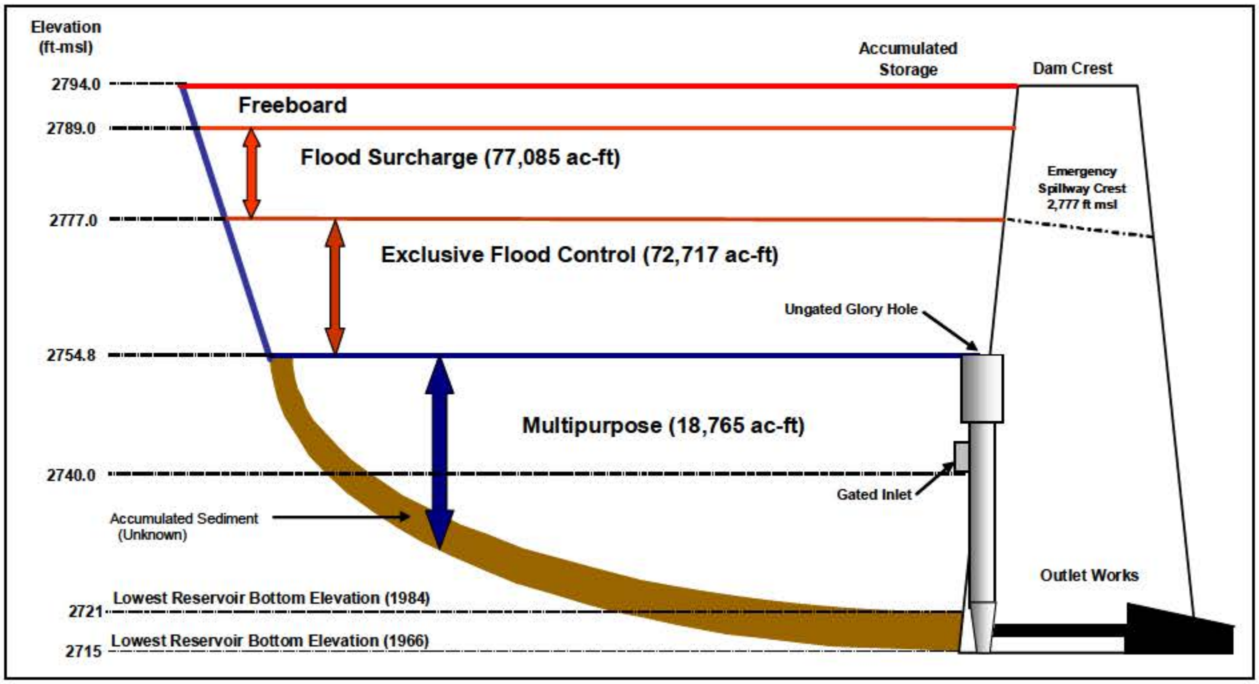

Figure 7.1. Current storage zones of Bowman-Haley Reservoir based on the 1984 survey data.

7.1.1.5 Historic Water Quality Concerns

Historic water quality data collection indicated that Bowman-Haley had extremely poor water quality with numerous exceedences of State water quality standards. Some authorized project purposes could not be met because of poor water quality. Due to the documented poor water quality, a public meeting was held in Bowman, North Dakota on April 8, 1985 to discuss procedures that might be employed to improve water quality in the reservoir. Installing a lower low-level outlet to release water from the bottom of the reservoir was discussed.

7.1.1.6 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Bowman-Haley Reservoir since the 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Recently, the District has scaled back water quality monitoring at Bowman-Haley Reservoir, and is targeting to monitor the reservoir every 3 years. Figure 7.2 shows the location of the sites that are targeted for current water quality monitoring. During the past 5 years, the District conducted water quality monitoring at Bowman-Haley Reservoir in 2002, 2003, and 2004.

7.1.2 Existing Water Quality Conditions (2002 through 2006)

7.1.2.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Bowman-Haley Reservoir at sites BOWLKND1, BOWLKMLN1, and BOWLKMLS1 from May through September during the period 2002 through 2004 are summarized, respectively, in Plates 147 through 149. A review of these results indicated possible water quality concerns regarding dissolved oxygen, pH, and ammonia.

Figure 7.2. Location of sites where water quality monitoring was conducted at Bowman-Haley Reservoir during the period 2002 through 2004, and will be targeted for future monitoring.

A minor number of dissolved oxygen measurements (i.e., < 10%) in the area of the dam and north arm of Bowman-Haley Reservoir were below the 5 mg/l criterion for the protection of aquatic life (Plates 147 and 148). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and may have been associated with thermal stratification.

An appreciable number of pH readings measured throughout Bowman-Haley Reservoir were above the numeric pH criteria of 9.0 for the protection of aquatic life (Plates 147 - 149). The magnitude and number of pH criterion exceedences seemingly do not indicate a significant water quality concern at this time. It is believed the high pH values may be associated alkaline soils of the area.

The chronic ammonia criterion for the protection of aquatic life was seemingly exceeded in Bowman-Haley Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

7.1.2.2 Summer Thermal Stratification

Existing summer thermal stratification of Bowman-Haley Reservoir, at the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 150). The plotted depth-profile temperature measurements indicate that the reservoir seldom exhibits significant summer thermal stratification (Plate 150). Based on the seldom occurrence of significant thermal stratification in the summer, Bowman-Haley Reservoir appears to be polymixic.

7.1.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions in Bowman-Haley Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 151). Only rarely was a significant vertical gradient in summer dissolved oxygen levels apparent (Plate 151). Bowman-Haley Reservoir appears to be polymixic.

7.1.2.4 Water Clarity

Figure 7.3 displays a box plot of the Secchi depth transparencies measured at the three in-reservoir monitoring sites (i.e., BOWLKND1, BOWLKMLN1, and BOWLKMLS1) during the 2002 through 2004 period (note: the monitoring sites are oriented in an upstream to downstream direction). Water clarity in the reservoir was highest in the north arm and lowest in the south arm; while the area near the dam was intermediary (Figure 7.2). The differing water clarity in the two arms of the reservoir can be seen in the 2006 aerial photo of the reservoir (Figure 7.2).

7.1.2.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Bowman-Haley Reservoir during the summers of 2002 through 2004 in the near-dam, deepwater area (i.e. site BOWLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the surface, and near-bottom samples were defined as samples collected within 1 meter of the bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, orthophosphorus, and total organic carbon (Plate 152). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. No parameters varied significantly between the surface and the bottom (Plate 152).

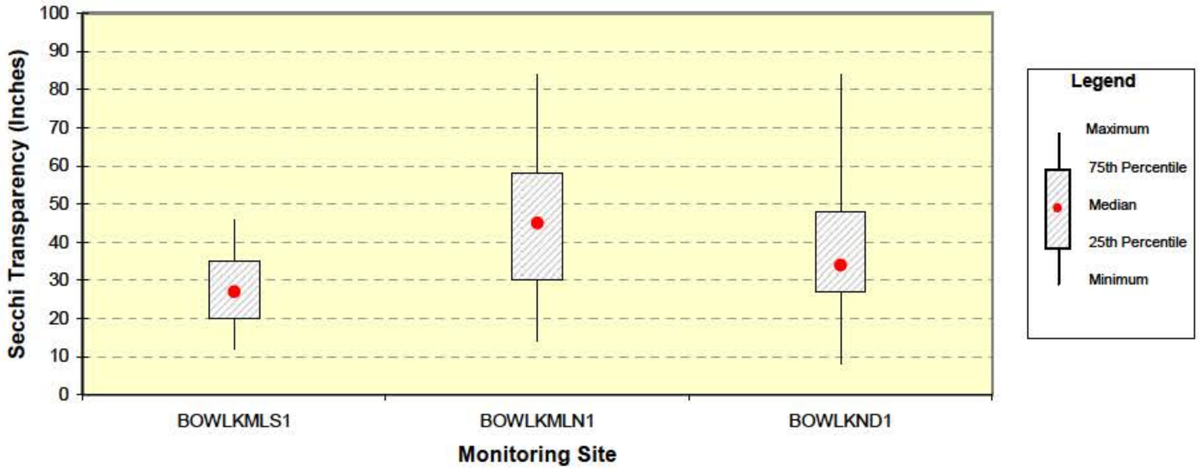

Figure 7.3. Box plot of Secchi depth transparencies measured in Bowman-Haley Reservoir during the 3-year period 2002 through 2004.

7.1.2.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Bowman-Haley Reservoir were calculated from monitoring data collected during the period 2002 through 2004 at the near-dam ambient monitoring site (i.e., BOWLKND1). Table 7.2 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Bowman-Haley Reservoir is in a eutrophic condition.

Table 7.2. Summary of Trophic State Index (TSI) values calculated for Bowman-Haley Reservoir for the 3-year period of 2002 through 2004.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	12	61	60	49	83
TSI(TP)	14	62	63	52	69
TSI(Chl)	8	56	55	40	81
TSI(Avg)	15	60	60	49	71

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

7.1.3 WATER QUALITY TRENDS (1980 THROUGH 2004)

Water quality trends from 1980 to 2004 were determined for Bowman-Haley Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., BOWLKND1). Plate 153 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Bowman-Haley Reservoir exhibited an increasing trend in transparency, and decreasing trends in total phosphorus, and chlorophyll *a*. Over the 25-year period since 1980, Bowman-Haley Reservoir has remained in a eutrophic condition (Plate 153).

7.2 PIPESTEM RESERVOIR

7.2.1 BACKGROUND INFORMATION

7.2.1.1 Project Overview

The dam forming Pipestem Reservoir is located on Pipestem Creek, 3 miles northwest of Jamestown, North Dakota. The dam was completed in July 1973 and the reservoir reached its initial fill in May 1974. The Pipestem Reservoir watershed is 594 square miles. The watershed was largely agricultural and rangeland when the dam was built in 1974 and has remained so to the present time. The authorized project purposes of Pipestem Reservoir are flood control, recreation, fish and wildlife, and water quality.

7.2.1.2 Pipestem Dam Intake Structure

The intake at Pipestem Dam is an ungated drop inlet with a weir elevation of 1442.4 ft-msl. The intake structure has two 4 feet x 7 feet hydraulic slide service gates and two low-level gates. The two low-level gates are a 3 foot x 3 foot slide gate at invert elevation 1433.0 ft-msl, and a 3 foot diameter slide gate at invert elevation 1415.0 ft-msl. Since the top of the multipurpose pool is also the crest of the ungated weir, no specific regulation of water levels of the multipurpose pool is required. Regulation for conservation will normally be automatic in that the incoming water will flow over the weir crest. The two low-level gates allow for the release of water from the multipurpose pool. The higher outlet is designed to meet water quality and downstream requirements. The lower outlet is provided for emergency drainage of the reservoir but may also be used for other purposes.

7.2.1.3 Reservoir Storage Zones

Figure 7.2 depicts the current storage zones of Pipestem Reservoir based on the 1990 survey data and estimated sedimentation. It is estimated that 3 percent of the Multipurpose Pool has been lost to sedimentation as of 2006. The 1990 sedimentation survey data has been called into question, and a sedimentation survey planned for 2007 will allow sedimentation rates to be verified.

7.2.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

The State of North Dakota has designated Pipestem Reservoir as a Class 3 lake in the State's water quality standards. The beneficial uses designated for Class I streams are also applicable to all classified lakes in North Dakota. As such, the beneficial uses designated for Pipestem Reservoir are: primary contact recreation, warmwater fishery, wildlife, and agricultural water supply. Water quality is also to be suitable for municipal or domestic use after appropriate treatment. The reservoir is not directly used as a municipal or domestic water supply.

Pursuant to the Federal CWA, the State of North Dakota has listed Pipestem Reservoir on the State's 2006 Section 303(d) list (see Table 1.3). The beneficial use identified as fully supported but threatened is recreation. The impairment of the use is attributed to nutrients and eutrophication. The development of a TDML for Pipestem Reservoir has been given a priority rating of 2 (i.e., scheduled for TMDL development in the next 10 years). The State of North Dakota has issued a statewide fish consumption advisory for mercury. As such, the advisory applies to Pipestem Reservoir.

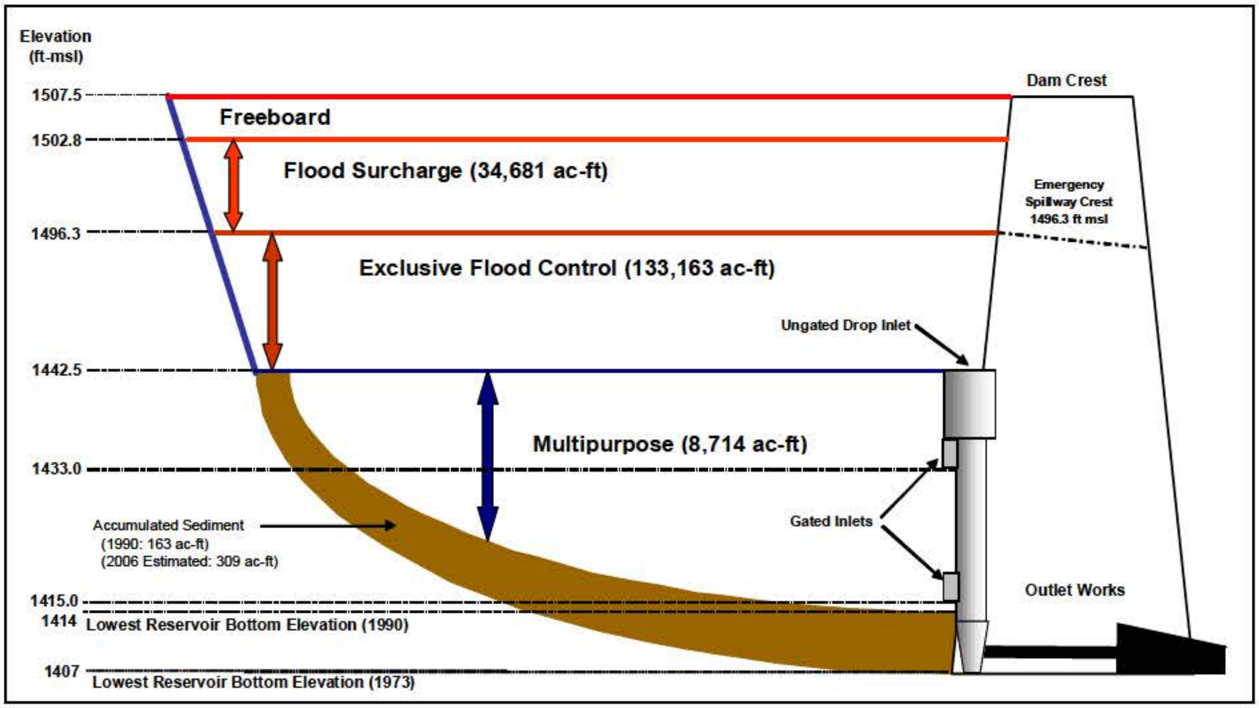

Figure 7.4. Current storage zones of Pipestem Reservoir based on the 1990 survey data and estimated sedimentation.

7.2.1.5 Historic Water Quality Concerns

Following the initial fill of the multipurpose pool in 1974 and prior to the spring runoff in 1975, water quality measurements indicated severe oxygen depletions existed in the reservoir under the ice cover. Further investigations confirmed that elevated levels of nitrogen, phosphorus, and organic matter occurred near the bottom of the reservoir. In an effort to improve the recreational and fish and wildlife quality of the reservoir, a sluicing operation was conducted using the lower low-level outlet to draw off the poor quality water near the reservoir bottom. The decision was made to proceed with this operation after it was determined that the impending snowmelt runoff would fill the reservoir to the multipurpose pool. The low-level releases were monitored during the operation, and it was found that the released water was rapidly oxygenated and did not cause any adverse affects downstream.

Current operations at Pipestem dam include keeping the lower low-level gate open during periods when water is flowing over the crest of the drop inlet structure in an effort to draw some water from the reservoir bottom and improve the water quality in the reservoir.

7.2.1.6 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Pipestem Reservoir since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Recently, the District has scaled back water quality monitoring at Pipestem Reservoir, and is targeting to monitor the reservoir every 3 years. Figure 7.5 shows the location of the sites that are targeted for current water quality monitoring. During the past 5 years, the District conducted water quality monitoring at Pipestem Reservoir in 2002, 2003, and 2004.

Figure 7.5. Location of sites where water quality monitoring was conducted at Pipestem Reservoir during the period 2002 through 2004, and will be targeted for future monitoring.

7.2.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

7.2.2.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Pipestem Reservoir at sites PIPLKND1 and PIPLKML1 from May through September during the period 2002 through 2004 are summarized, respectively, in Plates 154 and 155. A review of these results indicated possible water quality concerns regarding dissolved oxygen and ammonia.

An appreciable number of dissolved oxygen measurements (i.e., > 10%) throughout Pipestem Reservoir were below the 5 mg/l criterion for the protection of aquatic life (Plates 154 and 155). Most of the low dissolved oxygen measurements occurred near the bottom of the reservoir, and appeared to have been associated with summer thermal stratification.

The chronic ammonia criterion for the protection of aquatic life was seemingly exceeded in Pipestem Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

7.2.2.2 Summer Thermal Stratification

Existing summer thermal stratification of Pipestem Reservoir, in the deep water area near the dam, is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summers of 2002 through 2004 were compiled (Plate 156). The plotted depth-profile temperature measurements indicate that the reservoir regularly exhibits significant summer thermal stratification (Plate 156). Significant thermal stratification appears to be present in Pipestem Reservoir during mid-summer (i.e., July and August).

7.2.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions in Pipestem Reservoir, in the deep water area near the dam, are described by the depth-profile dissolved oxygen plots measured over the 3-year period 2002 through 2004 (Plate 157). Significant vertical gradients in dissolved oxygen levels occurred during mid-summer when significant thermal stratification was present. During these periods, a clinograde vertical distribution of dissolved oxygen is apparent (Plate 157).

7.2.2.4 Water Clarity

Figure 7.6 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., PIPLKND1 and PIPLKML1) during the period 2002 through 2004 (note: the monitoring sites are oriented in an upstream to downstream direction). Water clarity in the reservoir was noticeably higher near the dam as compared to mid-reservoir (Figure 7.6)

7.2.2.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Pipestem Reservoir during the summers of 2002 through 2004 in the near-dam, deepwater area (i.e. site PIPLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the surface, and near-bottom samples were defined as samples collected within 1 meter of the bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total

ammonia, nitrate-nitrate nitrogen, total phosphorus, orthophosphorus, and total organic carbon (Plate 158). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen varied significantly between the surface and the bottom (Plate 158). Measured dissolved oxygen concentrations were significantly lower near the reservoir bottom.

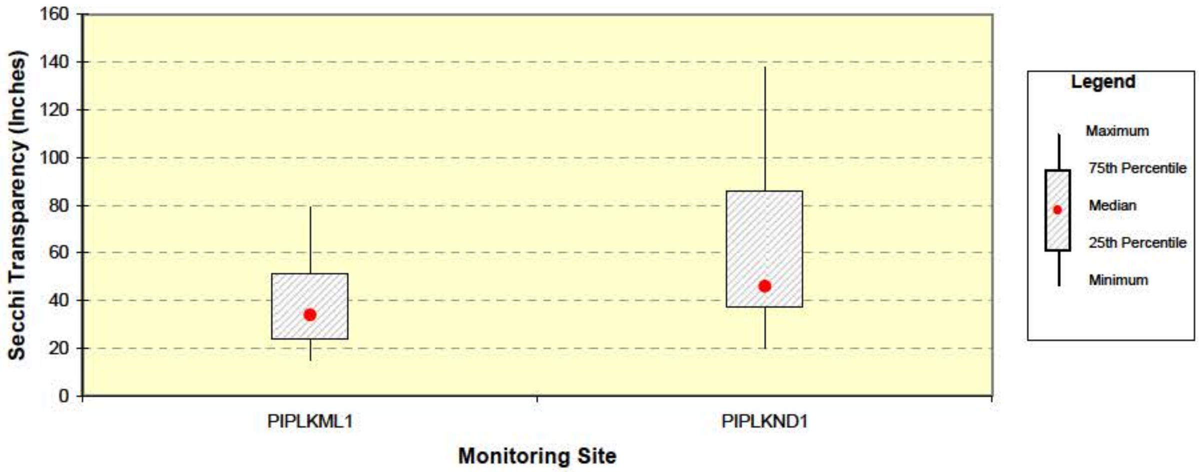

Figure 7.6. Box plot of Secchi depth transparencies measured in Pipestem Reservoir during the 3-year period 2002 through 2004.

7.2.2.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Pipestem Reservoir were calculated from monitoring data collected during the period 2002 through 2004 at the near-dam ambient monitoring site (i.e., PIPLKND1). Table 7.3 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Pipestem Reservoir is in a eutrophic to hypereutrophic condition.

Table 7.3. Summary of Trophic State Index (TSI) values calculated for Pipestem Reservoir for the 3-year period of 2002 through 2004.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	15	56	58	42	70
TSI(TP)	15	76	77	66	83
TSI(Chl)	12	65	66	46	77
TSI(Avg)	15	65	65	55	75

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

7.2.3 WATER QUALITY TRENDS (1980 THROUGH 2004)

Water quality trends from 1980 to 2004 were determined for Pipestem Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., PIPLKND1). Plate 159 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Pipestem Reservoir exhibited increasing trends in transparency and total phosphorus, and a decreasing trend in chlorophyll *a*. Over the 25-year period since 1980, Pipestem Reservoir has remained in a eutrophic to hypereutrophic condition (Plate 159).

8 SOUTH DAKOTA TRIBUTARY PROJECTS

Two District tributary reservoir projects are located in South Dakota: Cold Brook and Cottonwood Springs. Both reservoirs are located in southwest South Dakota in the Black Hills area (Figure 1.1). Table 8.1 gives selected engineering data for the Cold Brook and Cottonwood Springs Projects.

8.1 COLD BROOK RESERVOIR

8.1.1 BACKGROUND INFORMATION

8.1.1.1 Project Overview

The dam forming Cold Brook Reservoir is located on Cold Brook Creek, approximately 1-mile upstream from its confluence with the Fall River, and 2 miles north of Hot Springs, South Dakota. The dam was completed in September 1952 and the reservoir reached its initial fill in June 1963. The Cold Brook Reservoir watershed is 70.5 square miles. The watershed was largely rangeland and forested when the dam was built in 1952 and has remained so to the present time. The authorized project purposes of Cold Brook Reservoir are flood control, recreation, fish and wildlife, and water quality.

8.1.1.2 Cold Brook Dam Intake Structure

The intake structure at Cold Brook Dam is a circular (6.67 ft inside diameter) freestanding tower of reinforced concrete having an ungated bell-mouthed entrance. Supported on four buttress-type spread footings, the tower stands in the deepest part of the reservoir, about 70 feet upstream from the toe of the dam. The crest of the bell-mouthed entrance is at elevation 3600.0 ft-msl. Four port openings, each 1.2 high by 3.0 feet wide, are spaced evenly around the periphery of the vertical tower at elevation 3585.0 ft-msl, which is the upper limit of the conservation pool. Lowering of the surface of the conservation pool to a minimum elevation of 3548 ft-msl is accomplished by manual control of three 12-inch gate values located in the footings of the tower which discharge through the openings into the conduit.

Three 8-inch diameter inlets were originally provided at elevations 3580.0, 3560.0, and 3548.0 ft-msl as intakes for the Larvie Lake supply line. The inlets were modified in 1978 to enhance the water supply to Larvie Lake. The lowest inlet (i.e., elevation 3548.0 ft-msl) was located on the bottom of the reservoir and was abandoned due to the excessive amount of silts that were captured by the inlet and passed to Larvie Lake. Inlet covers were placed on both faces of the inlet at this elevation to seal the opening. Similar inlet covers were placed on the left side of the structure legs over the inlets at 3580.0 and 3560.0 ft-msl. Slide gates were placed over the right side of the inlet openings. A gate stem was extended from the gates to the grating deck where a gate lift mechanism was constructed to the structure leg.

8.1.1.3 Reservoir Storage Zones

Figure 8.1 depicts the current storage zones of Cold Brook Reservoir based on 1972 computations. The District has not conducted sediment surveys at Cold Brook Reservoir; therefore, the current amount of sedimentation has not been estimated and is unknown.

Table 8.1. Summary of selected engineering data for the Cold Brook and Cottonwood Springs Projects.

	Cold Brook Reservoir	Cottonwood Springs Reservoir
General		
Dammed Stream	Cold Brook Creek	Cottonwood Springs Creek
Drainage Area	70 5 sq mi	26 sq mi
Reservoir Length[1]	1 2 miles	0 6 miles
Multipurpose Pool Elevation (Top)	3585 0 ft-msl	3875 0 ft-msl
Date of Dam Closure	September 1952	May 1969
Date of Initial Fill[2]	June 1963	Not yet reached
"As-Built" Conditions[3]	(1972 Computations)	(1971 Computations)
Lowest Reservoir Bottom Elevation	3539 ft-msl	3839 ft-msl
Surface Area at top of Multipurpose Pool	36 ac	44 ac
Capacity to top of Multipurpose Pool	520 ac-ft	655
Mean Depth at top of Multipurpose Pool[4]	14 4 ft	14 9 ft
Latest Surveyed Conditions	(1972 Computations)	(1971 Computations)
Lowest Reservoir Bottom Elevation	3539 ft-msl	3839 ft-msl
Surface Area at top of Multipurpose Pool	36 ac	44 ac
Capacity of Multipurpose Pool	520 ac-ft	655
Mean Depth at top of Multipurpose Pool[4]	14 4 ft	14 9 ft
Sediment Deposition in Multipurpose Pool		
Historic Sediment Deposition[5]	Unknown[9]	Unknown[9]
Annual Sedimentation Rate[6]	Unknown[9]	Unknown[9]
Current Estimated Sediment Deposition[7]	Unknown[9]	Unknown[9]
Current capacity of Multipurpose Pool[8]	Unknown[9]	Unknown[9]
Percent of "As-Built" Multipurpose Pool capacity lost to current estimated sediment deposition	Unknown[9]	Unknown[9]
Operational Details – Historic	(1964 – 2006)	(1973 – 2006)
Maximum Recorded Pool Elevation	3585 6 ft-msl 20-Jun-99	3872 7 ft-msl 23-Mar-00
Minimum Recorded Pool Elevation	3576 6 ft-msl 22-Oct-77	3832 4 ft-msl 30-Sep-89
Maximum Recorded Daily Inflow	74 cfs 14-Jul-62	52 cfs 20-Aug-93
Maximum Recorded Daily Outflow	19 cfs 4-Jul-99	No Outflow
Average Annual Pool Elevation	3582 0 ft-msl	3848 4
Average Annual Inflow	683 ac-ft	35 ac-ft
Average Annual Outflow	582 ac-ft	No Outflow
Estimated Retention Time[10]	0 89 Years	-----
Operational Details – Current[11]		
Maximum Recorded Pool Elevation	3585 3 ft-msl 12-Mar-06	3854 3 ft-msl 1-Oct-05
Minimum Recorded Pool Elevation	3581 9 ft-msl 2-Nov-05	3848 5 ft-msl 30-Sep-06
Maximum Recorded Daily Inflow	2 3 cfs 14-Dec-05	0 cfs
Maximum Recorded Daily Outflow	4 2 cfs 6-Apr-06	No Outflow
Total Inflow (% of Normal)	556 ac-ft (82%)	0 ac-ft (0%)
Total Outflow (% of Normal)	451 ac-ft (78%)	No Outflow
Outlet Works		
Ungated Outlets	Drop Inlet 3585 0 ft-msl	Drop Inlet 3875 0 ft-msl
Gated Outlets (Mid-depth)	1) 8" Dia Slide Gate 3580 0 ft-msl 1) 8" Dia Slide Gate 3560 0 ft-msl	1) 3'x 3' Slide Gate 3868 0 ft-msl
Gated Outlets (Low-level)	3) 12" Gate Valves 3548 0 ft-msl	

[1] Reservoir length at top of conservation pool
[2] First occurrence of reservoir pool elevation to top of multipurpose pool elevation
[3] "As-Built" conditions taken to be the conditions present when the reservoir was first surveyed
[4] Mean Depth = Volume ÷ Surface Area
[5] Difference in reservoir storage capacity to top of Multipurpose Pool between "as-built" and latest survey
[6] Annualized rate based on historic accumulated sediment
[7] Current accumulated sediment estimated from historic annual sedimentation rate
[8] Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation
[9] Unable to caluculate accumulated sediment and sediment deposition rates becauseno bathymetric surveys conducted on either reservoir
[10] Estimated Retention Time = Multipurpose Pool Volume ÷ Average Annual Outflow
[11] Current operational details are for the water year 1-Oct-2005 through 30-Sep-2006

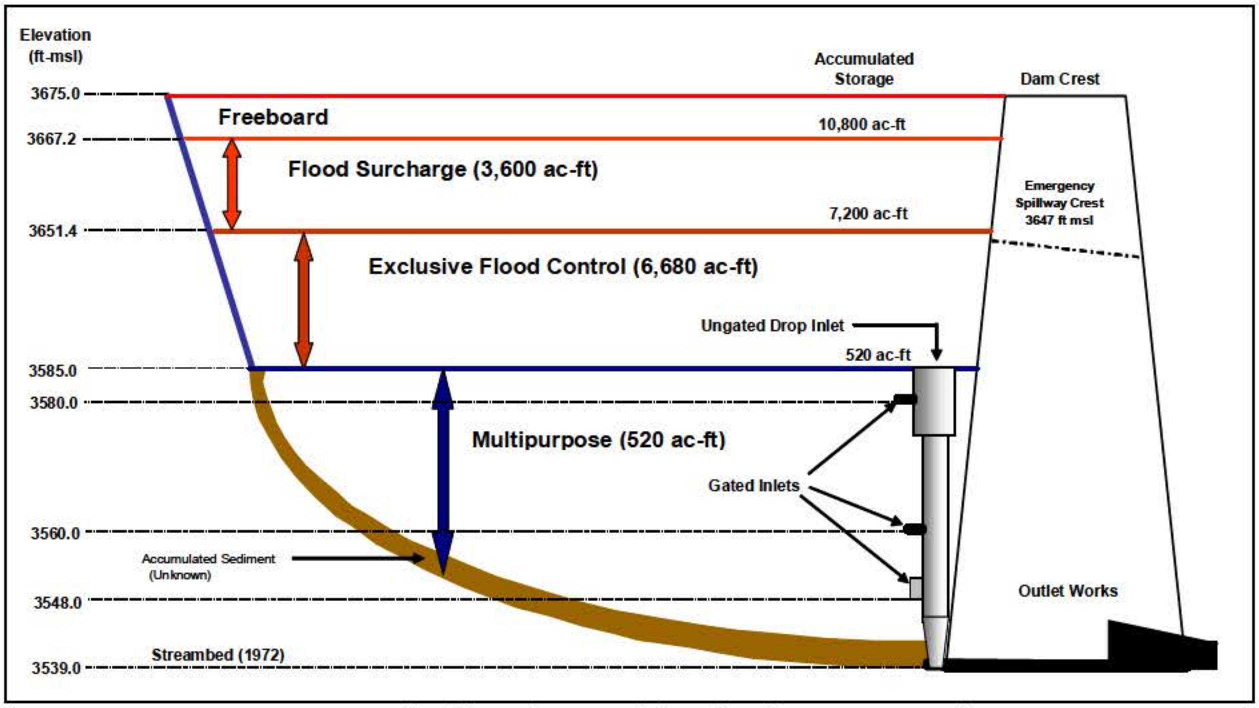

Figure 8.1. Current storage zones of Cold Brook Reservoir based on the 1972 computations.

8.1.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

As identified in the State of South Dakota's water quality standards, the following beneficial uses are designated for Cold Brook Reservoir: recreation (immersion and limited contact), coldwater permanent fish life propagation, fish and wildlife propagation, stock watering, and domestic water supply. The reservoir is not directly used as a municipal or domestic water supply. Pursuant to the Federal CWA, the State of South Dakota has not listed Cold Brook Reservoir on the State's 2006 Section 303(d) list. The State of South Dakota also has not issued a fish consumption advisory for the reservoir.

8.1.1.5 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Cold Brook Reservoir since the 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Recently, the District has scaled back water quality monitoring at Cold Brook Reservoir, and is targeting to monitor the reservoir every 3 years. Monitoring was scheduled for 2005, but was not conducted because low water conditions restricted access. Figure 8.2 shows the location of the sites that are targeted for current water quality monitoring. During the past 5 years, the District conducted water quality monitoring at Cold Brook Reservoir in 2002 and 2003.

Figure 8.2. Location of sites where water quality monitoring was conducted at Cold Brook Reservoir during the period 2002 through 2003, and will be targeted for future monitoring.

8.1.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

8.1.2.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Cold Brook Reservoir at sites CODLKND1 and CODLKML1 from May through September during 2002 and 2003 are summarized, respectively, in Plates 160 and 161. A review of these results indicated possible water quality concerns regarding water temperature, dissolved oxygen, ammonia, and arsenic.

The temperature criterion of 65° F (18.3°C) for the protection of coldwater permanent fish life propagation was exceeded by over 70 percent of measurements taken in Cold Brook Reservoir. It is noted that if the reservoir were classified for the protection of coldwater marginal fish life propagation the criterion of 75°F (23.8°C) would have been exceeded by less than 30% of the measurements. The temperature criterion of 80°F (26.6°C) for the protection of warmwater permanent fish life propagation would not have been exceeded at any time. Ambient water temperatures in Cold Brook Reservoir do not appear to be cold enough to support coldwater permanent fish life propagation as defined by State water quality standards criteria. Consideration should be given to reclassify Cold Brook Reservoir for either coldwater marginal fish life propagation or warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

Dissolved oxygen criteria were exceeded by less than 10 percent of the dissolved oxygen measurements taken in Cold Brook Reservoir. The lower dissolved oxygen concentrations occurred in the deeper part of the measured depth profile and were associated with a temperature gradient. The lower dissolved oxygen concentrations in the deeper water of Cold Brook Reservoir may be a concern if a coldwater fishery is to be supported. Water temperatures appear marginal in Cold Brook Reservoir for supporting a coldwater fishery, and the colder water that occurs in the reservoir is in the deeper portions where the lower dissolved oxygen levels occur.

The chronic ammonia criterion for the protection of aquatic life was seemingly exceeded by one measurement in Cold Brook Reservoir in the area near the dam. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred.

The arsenic human health criterion for surface waters was exceeded by both of the arsenic measurements sampled in Cold Brook Reservoir. The arsenic criterion for human health protection is extremely low (i.e., 0.018 ug/l), and the measured arsenic levels were well below the criteria for the protection of aquatic life.

8.1.2.2 Summer Thermal Stratification

Existing summer thermal stratification of Cold Brook Reservoir, in the deep water area near the dam, is described by the depth-profile temperature plots measured during 2002 and 2003. Depth-profile temperature plots measured during the summer were compiled (Plate 162). The plotted depth-profile temperature measurements indicate that the reservoir regularly exhibits significant summer thermal stratification (Plate 162). Significant thermal stratification appears to be present in Cold Brook Reservoir during mid-summer.

8.1.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions in Cold Brook Reservoir, in the deep water area near the dam, are described by the depth-profile dissolved oxygen plots measured over the 2-year period

2002 through 2003 (Plate 163). Significant vertical gradients in dissolved oxygen levels occurred during mid-summer when significant thermal stratification was present. During these periods, anoxic conditions (i.e., dissolved oxygen concentrations < 2 mg/l) develop near the reservoir bottom (Plate 163).

8.1.2.4 Water Clarity

Figure 8.3 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., CODLKND1 and CODLKML1) during 2002 and 2003 (note: the monitoring sites are oriented in an upstream to downstream direction). Water clarity measured at the two sites was very high and similar (Figure 8.3).

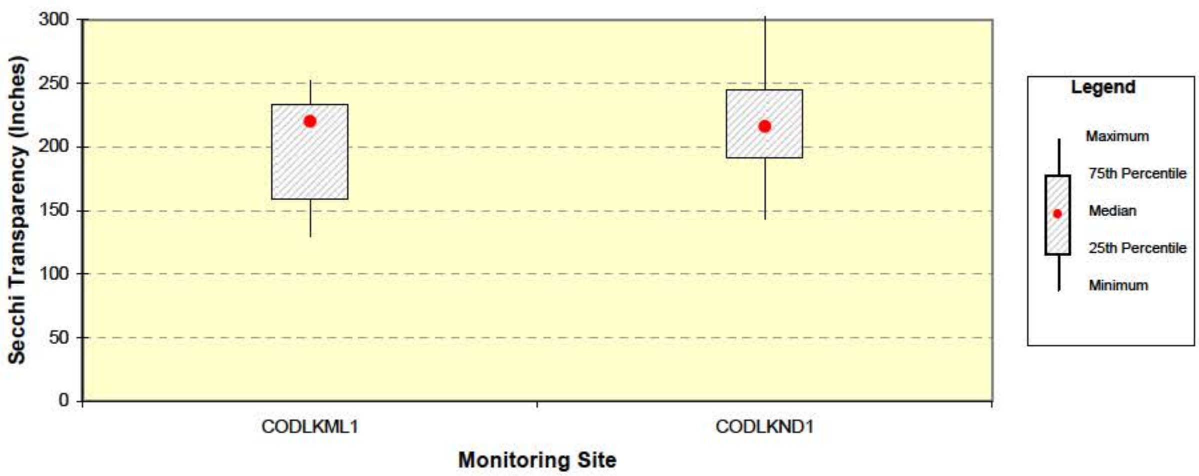

Figure 8.3. Box plot of Secchi depth transparencies measured in Cold Brook Reservoir during the 2-year period 2002 through 2003.

8.1.2.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Cold Brook Reservoir during the summers of 2002 and 2003 in the near-dam, deepwater area (i.e. site CODLKND1) were compared. Near-surface samples were defined to be samples collected within 1 meter of the surface, and near-bottom samples were defined as samples collected within 1 meter of the bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential, total Kjeldahl nitrogen, total ammonia, nitrate-nitrate nitrogen, total phosphorus, orthophosphorus, and total organic carbon (Plate 164). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. One parameter, dissolved oxygen varied significantly between the surface and the bottom (Plate 164). Measured dissolved oxygen concentrations were significantly lower near the reservoir bottom.

8.1.2.6 Reservoir Trophic State

Trophic State Index (TSI) values for Cold Brook Reservoir were calculated from monitoring data collected during the period 2002 and 2003 at the near-dam ambient monitoring site (i.e., CODLKND1). Table 8.2 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Cold Brook Reservoir is in a mesotrophic condition.

Table 8.2. Summary of Trophic State Index (TSI) values calculated for Cold Brook Reservoir for the 2-year period of 2002 through 2003.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	8	31	36	35	41
TSI(TP)	8	41	50	52	57
TSI(Chl)	4	40	46	46	53
TSI(Avg)	8	38	43	43	49

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.
Note: See Section 4.1.3 for discussion of TSI calculation.

8.1.3 WATER QUALITY TRENDS (1980 THROUGH 2006)

Water quality trends from 1980 to 2003 were determined for Cold Brook Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., trophic condition). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., CODLKND1). Plate 165 displays a scatter-plot of the collected data for the four parameters and a linear regression line. For the assessment period, Cold Brook Reservoir exhibited increasing trends in transparency and total phosphorus, and a decreasing trend in chlorophyll *a*. Over the 24-year period since 1980, Cold Brook Reservoir has remained in a mesotrophic condition (Plate 165).

8.2 COTTONWOOD SPRINGS RESERVOIR

8.2.1 BACKGROUND INFORMATION

8.2.1.1 Project Overview

The dam forming Cottonwood Springs Reservoir is located on Cottonwood Springs Creek, approximately 5 miles west of Hot Springs, South Dakota. The dam was completed in May 1969 and the reservoir has not reached an initial fill. The Cottonwood Springs Reservoir watershed is 26 square miles. The watershed was largely rangeland and forested when the dam was built in 1952 and has remained so to the present time. The authorized project purposes of Cottonwood Springs Reservoir are flood control, recreation, fish and wildlife, and water quality.

8.2.1.2 Cottonwood Springs Dam Intake Structure

The intake at Cottonwood Springs Dam is a drop inlet structure consisting of a single reinforced concrete box shaft. Its inside dimensions are 4 feet by 8 feet. The structure was designed and constructed so that normal and flood period pool regulation is automatic. The intake structure has two ungated openings, each 42” x 96”, with a weir crest elevation of 3875.0 ft-msl. The weir crest elevation of 3875.0 ft-msl is the water surface elevation of the multipurpose pool. A 36” x 36” gated opening with a crest elevation of 3868.0 ft-msl was constructed into the upstream face of the intake structure. The gated outlet may be used to release water for downstream needs.

8.2.1.3 Reservoir Storage Zones

Figure 8.1 depicts the current storage zones of Cottonwood Springs Reservoir based on the 1971 as-built conditions. The District has not conducted sediment surveys at Cottonwood Springs Reservoir; therefore, the current amount of sedimentation has not been estimated and is unknown.

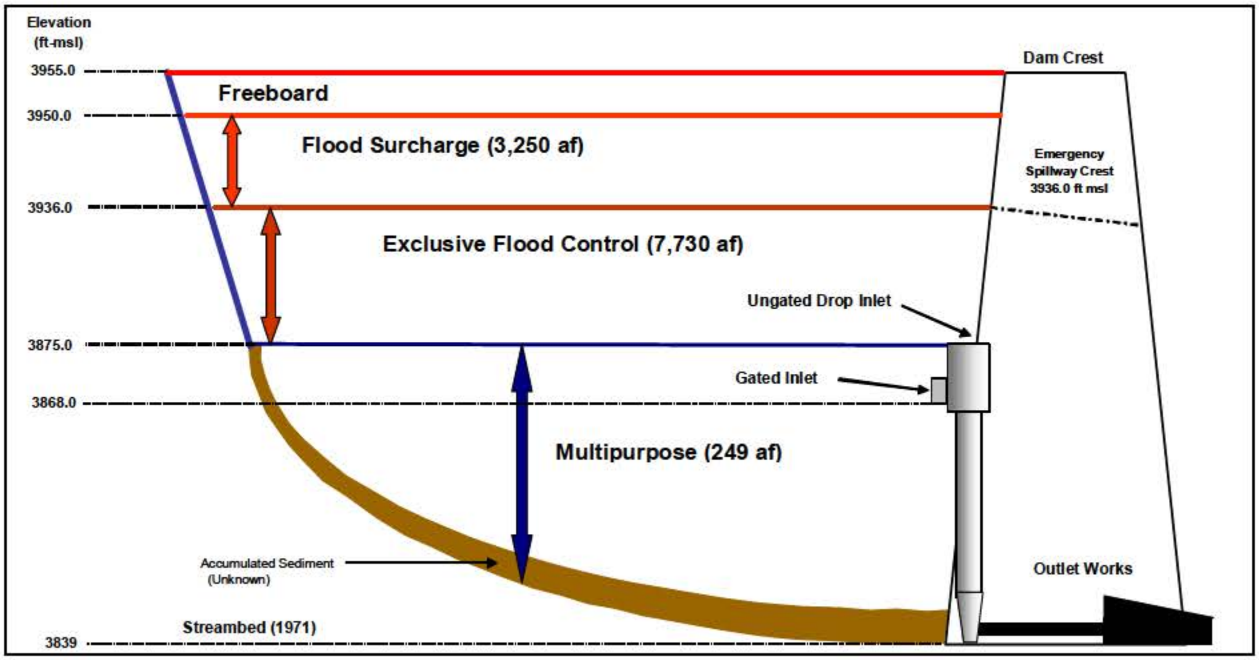

Figure 8.4. Current storage zones of Cottonwood Springs Reservoir based on the 1971 "as-built" conditions.

8.2.1.4 Water Quality Standards Classifications, Section 303(d) Listings, and Fish Consumption Advisories

As identified in the State of South Dakota's water quality standards, the following beneficial uses are designated for Cottonwood Springs Reservoir: recreation (immersion and limited contact), warmwater permanent fish life propagation, fish and wildlife propagation, stock watering, and domestic water supply. The reservoir is not directly used as a municipal or domestic water supply. Pursuant to the Federal CWA, the State of South Dakota has not listed Cottonwood Springs Reservoir on the State's 2006 Section 303(d) list. The State of South Dakota also has not issued a fish consumption advisory for the reservoir.

8.2.1.5 Ambient Water Quality Monitoring

The District has irregularly monitored water quality conditions at Cottonwood Reservoir since the 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow and outflow of the reservoir. Recently, the District has scaled back water quality monitoring at Cottonwood Springs Reservoir, and is targeting to monitor the reservoir every 3 years. Monitoring was scheduled for 2005, but was not conducted because low water conditions restricted access. Figure 8.5 shows the location of the sites that are targeted for current water quality monitoring. During the past 5 years, the District conducted water quality monitoring at Cottonwood Springs Reservoir in 2002.

Figure 8.5. Location of sites where water quality monitoring was conducted at Cottonwood Springs Reservoir during 2002, and will be targeted for future monitoring.

8.2.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

8.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Criteria

Water quality conditions that were monitored in Cottonwood Springs Reservoir at sites COTLKND1 and COTLKML1 from May through September during 2002 are summarized, respectively, in Plates 166 and 167. A review of these results indicated possible water quality concerns regarding dissolved oxygen.

Dissolved oxygen criteria were exceeded by about 10 percent of the dissolved oxygen measurements taken in Cottonwood Springs Reservoir. The lower dissolved oxygen concentrations occurred in the deeper part of the measured depth profile and were associated with a temperature gradient.

8.2.2.2 Summer Thermal Stratification

Existing summer thermal stratification of Cottonwood Springs Reservoir, in the deep water area near the dam, is described by the depth-profile temperature plots measured during 2002. Depth-profile temperature plots measured during the summer were compiled (Plate 168). The plotted depth-profile temperature measurements indicate that the reservoir showed significant thermal stratification during mid-summer (Plate 168).

8.2.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions in Cottonwood Springs Reservoir, in the deep water area near the dam, are described by the depth-profile dissolved oxygen plots measured during 2002 (Plate 169). Significant vertical gradients in dissolved oxygen levels occurred during mid-summer when significant thermal stratification was present. One profile exhibited anoxic conditions (i.e., dissolved oxygen concentrations < 2 mg/l) near the reservoir bottom (Plate 169).

8.2.2.4 Water Clarity

Figure 8.3 displays a box plot of the Secchi depth transparencies measured at the two in-reservoir monitoring sites (i.e., COTLKND1 and COTLKML1) during 2002 (note: the monitoring sites are oriented in an upstream to downstream direction). Water clarity measured at the two sites was very high and similar (Figure 8.6).

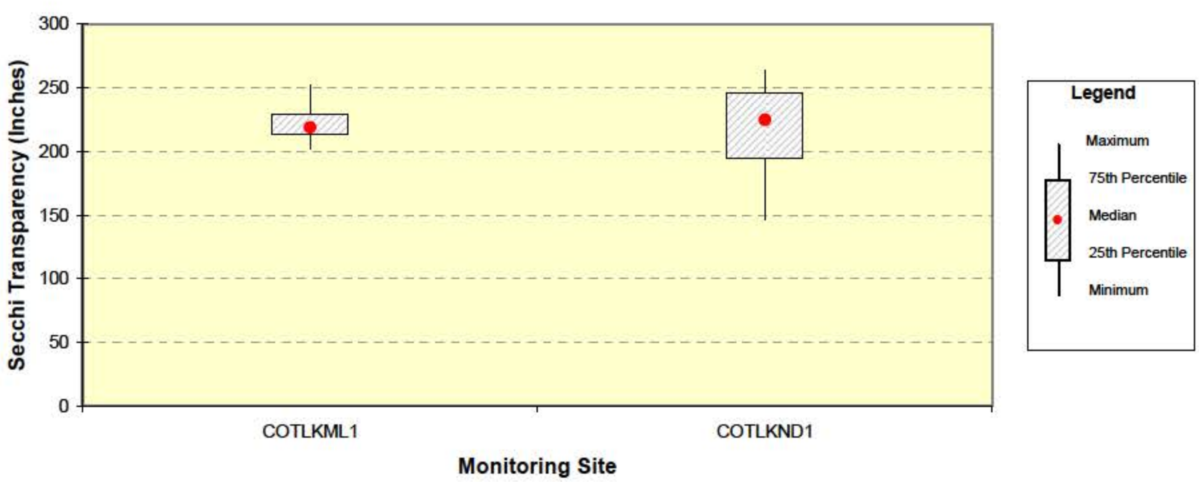

Figure 8.6. Box plot of Secchi depth transparencies measured in Cottonwood Springs Reservoir during 2002.

8.2.2.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Near-surface and near-bottom water quality conditions monitored in Cottonwood Springs Reservoir during the summer of 2002 in the near-dam, deepwater area (i.e. site COTLKND1) were compared. Near-surface samples were defined to be samples collected within 3 meters of the surface, and near-bottom samples were defined as samples collected within 1 meter of the bottom. Box plots were used to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, total Kjeldahl nitrogen, nitrate-nitrate nitrogen, total phosphorus, orthophosphorus, and total organic carbon (Plate 170). Non-overlapping interquartile ranges of the adjacent surface and bottom box plots for a parameter were taken to indicate a significant difference between the measurements. Three parameters, temperature, dissolved oxygen, and total phosphorus varied significantly between the surface and the bottom (Plate 170). Measured levels of all three parameters were significantly lower near the reservoir bottom (Plate 170).

8.2.2.6 Reservoir Trophic State

Trophic State Index (TSI) values for Cottonwood Springs Reservoir were calculated from monitoring data collected during 2002 at the near-dam ambient monitoring site (i.e., COTLKND1). Table 8.3 summarizes the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Cottonwood Springs Reservoir is in a mesotrophic condition.

Table 8.3. Summary of Trophic State Index (TSI) values calculated for Cottonwood Springs Reservoir for 2002.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	4	36	35	33	41
TSI(TP)	4	52	52	48	57
TSI(Chl)	-----	-----	-----	-----	-----
TSI(Avg)	4	44	43	41	49

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values.

Note: See Section 4.1.3 for discussion of TSI calculation.

9 WATER QUALITY MONITORING AND MANAGEMENT ACTIVITIES PLANNED FOR FUTURE YEARS

9.1 WATER QUALITY DATA COLLECTION

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years at the District's Tributary projects is given in Table 9.1. The identified data collection activities are considered the minimum needed to allow for the periodic assessment of water quality conditions. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

9.2 TOTAL MAXIMUM DAILY LOADS (TMDLS)

The District will participate, as appropriate, as a stakeholder in the development and implementation of TMDLs on water bodies that involve Tributary Projects.

Table 9.1. Water quality monitoring planned by the District's Water Quality Unit for District projects areas over the next 5 years and the intended data collection approach. Actual monitoring activities implemented will be dependent upon available resources.

Water Bodies to be Monitored	Long-Term Fixed Station Monitoring	Intensive Surveys	Special Studies	Watershed Assessments	Investigative Monitoring
Colorado Tributary Project Areas:					
• Bear Creek, Chatfield, and Cherry Creek Reservoirs	Other[a]				X[b]
Nebraska Tributary Project Areas:					
• Bluestem, Branched Oak, Conestoga, East Twin, Ed Zorinsky, Glen Cunningham, Holmes, Olive Creek, Pawnee, Stagecoach, Standing Bear, Wagon Train, Wehrspann, West Twin, and Yankee Hill Reservoirs	X[c]			X[d]	X[b]
North Dakota Tributary Project Areas:					
• Bowman-Haley and Pipestem Reservoirs	2007, 2010				X[b]
South Dakota Tributary Project Areas:					
• Cold Brook and Cottonwood Springs Reservoirs	2008, 2011				X[b]

[a] The District will utilize water quality data collected by the Local Watershed Management Authorities.
[b] Investigative Monitoring will be conducted as necessary and appropriate.
[c] To be monitored every year through 2009. The level of monitoring after 2009 will be dependent upon the continuance of a monitoring partnership with the Nebraska Department of Environmental Quality.
[d] Watershed Assessments will be implemented, as needed and resources allow, to facilitate development and evaluation of TMDLs in coordination with the Nebraska Department of Environmental Quality.

10 REFERENCES

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography, March 1977, Vol 22(2), pp. 361-369.

Health Canada. 2006. Blue-Green Algae (Cyanobacteria) and their toxins. http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/cyanobacteria-cyanobacteries_e.html.

U.S. Army Corps of Engineers. 1995. Engineer Regulation (ER) 1110-2-8154, Engineering and design – Water quality and environmental management for Corps civil works projects. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C.

_______. **2004.** Missouri River Mainstem Reservoir System, Master Water Control Manual, Missouri River Basin (March 2004). Reservoir Control Center, Northwestern Division – Missouri River Basin, U.S. Army Corps of Engineers. Omaha, Nebraska.

_______. **2006a.** Garrison cold water fishery performance report. Hydrologic Engineering Branch, Engineering Division, Omaha District, U.S. Army Corps of Engineers. Omaha, Nebraska.

_______. **2006b.** Water quality conditions monitored at the Corps' Garrison Project in North Dakota during the 3-year period 2003 through 2005. Water Quality Unit, Water Control and Water Quality Section, Hydrologic Engineering Branch, Engineering Division, Omaha District, U.S. Army Corps of Engineers. Omaha, Nebraska.

_______. **2007a.** Program Management Plan for Implementing the Omaha District's Water Quality Management Program. Water Quality Unit, Water Control and Water Quality Section, Hydrologic Engineering Branch, Engineering Division, Omaha District, U.S. Army Corps of Engineers. Omaha, Nebraska.

_______. **2007b.** Water Quality Conditions Monitored at the Corps' Fort peck Project in Montana during the 3-Year Period 2004 through 2006. Water Quality Unit, Water Control and Water Quality Section, Hydrologic Engineering Branch, Engineering Division, Omaha District, U.S. Army Corps of Engineers. Omaha, Nebraska.

U.S. Fish and Wildlife Service. 1993. Recovery plan for the pallid sturgeon (*Scaphirhynchus albus*). Pallid sturgeon recovery team. Region 6, U.S. Fish and Wildlife Service, Denver, Colorado.

11 PLATES

Plate 1. Summary of water quality conditions monitored in Ed Zorinsky Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site EZRLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1110.0	1110.1	1108.7	1110.8	-----	-----	-----
Water Temperature (C)	0.1	312	21.9	22.6	12.4	28.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	312	6.3	6.7	n.d.	11.0	≥ 5.0	66	21%
Dissolved Oxygen (% Sat.)	0.1	290	73.2	84.6	n.d.	135.6	-----	-----	-----
Specific Conductance (umho/cm)	1	300	451	449	351	573	-----	-----	-----
pH (S.U.)	0.1	300	8.2	8.3	7.0	10.1	≥6.5 & ≤9.0	8	3%
Turbidity (NTUs)	0.1	136	11.5	10.1	0.6	32.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	195	308	311	17	434	-----	-----	-----
Secchi Depth (in.)	1	25	45	30	17	120	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	140	140	110	195	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	0.31	0.23	n.d.	2.0	4.71 [1,2], 0.85 [1,3]	0, 2	0%, 6%
Chlorophyll *a* (ug/l) – Field Probe	1	66	6	5	n.d.	20	16[5]	8	12%
Chlorophyll *a* (ug/l) – Lab Determined	1	22	25	13	3	100	16[5]	9	41%
Hardness, Total (mg/l)	0.4	13	145	136	118	179	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	49	0.8	0.7	n.d.	3.1	-----	-----	-----
Nitrogen, Total (mg/)	0.1	47	0.9	0.9	n.d.	3.1	1.54[5]	4	9%
Nitrate-Nitrite N, Total (mg/l)	0.02	47	-----	n.d.	n.d.	0.20	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	49	0.08	0.05	0.01	0.49	0 143[56]	6	12%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	49	-----	n.d.	n.d.	0.41	-----	-----	-----
Suspended Solids, Total (mg/l)	4	49	-----	8	n.d.	28	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	5	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	6	8.0[2], 0.3[3]	0, 1	0%, 25%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	762[2], 99[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	18.0[2], 11.7[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	90[2], 3.5[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	607[2], 67[3]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	5 9[2]	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	4	152[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	23	-----	n.d.	n.d.	0.13	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	23	1.28	1.10	0.30	3.03	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	23	-----	0.12	n.d.	0.35	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	4	-----				*****	0	0%
Atrazine			0.67	0.41	0.35	1.50			
Isopropalin			-----	n.d.	n.d.	0.10			
Metolachlor			-----	n.d.	n.d.	0.10			
Metribuzin			-----	0.05	n.d.	0.14			
Profluralin			-----	n.d.	n.d.	0.48			
Propazine			-----	n.d.	n.d.	0.08			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 22.6 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 136 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 2. Summary of water quality conditions monitored in Ed Zorinsky Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site EZRLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1110.0	1110.1	1108.7	1110.8	-----	-----	-----
Water Temperature (C)	0.1	325	21.8	22.5	11.9	28.4	32	0	0%
Dissolved Oxygen (mg/l)	0.1	325	6.0	6.5	n.d.	11.6	≥ 5.0	83	26%
Dissolved Oxygen (% Sat.)	0.1	295	71.0	78.2	n.d.	131.6	-----	-----	-----
Specific Conductance (umho/cm)	1	309	4481	443	350	581	-----	-----	-----
pH (S.U.)	0.1	309	8.2	8.2	6.8	10.0	≥6.5 & ≤9.0	8	3%
Turbidity (NTUs)	0.1	153	13.3	10.8	1.1	37.8	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	216	315	367	-37	437	-----	-----	-----
Secchi Depth (in.)	1	24	39	28	15	132	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	85	7	4	n.d.	24	16(1)	8	12%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Nutrient criteria.

Plate 3. Summary of water quality conditions monitored in Ed Zorinsky Reservoir at the upstream, deepwater ambient monitoring location (i.e., site EZRLKUP1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at ½ the measured Secchi depth.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	25	1110.0	1110.1	1108.7	1110.8	-----	-----	-----
Water Temperature (C)	0.1	147	22.6	23.6	13.1	28.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	147	7.2	7.2	0.2	14.9	≥ 5.0	66	21%
Dissolved Oxygen (% Sat.)	0.1	135	86.1	87.3	2.8	174.9	-----	-----	-----
Specific Conductance (umho/cm)	1	141	427	432	291	530	-----	-----	-----
pH (S.U.)	0.1	141	8.3	8.3	7.4	9.7	≥6.5 & ≤9.0	7	5%
Turbidity (NTUs)	0.1	69	41.4	30.9	3.9	211.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	101	333	333	235	427	-----	-----	-----
Secchi Depth (in.)	1	24	19	18	8	60	-----	-----	-----
Alkalinity, Total (mg/l)	7	25	131	130	98	170	-----	-----	-----
Ammonia, Total (mg/l)	0.01	15	0.0.17	0.05	n.d.	0.63	$4.71^{(1,2)}$, $0.85^{(1,3)}$	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	34	17	15	n.d.	43	$16^{(5)}$	15	44%
Chlorophyll *a* (ug/l) – Lab Determined	1	22	26	14	3	180	$16^{(5)}$	10	45%
Hardness, Total (mg/l)	0.4	7	137	130	120	173	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	25	1.0	1.1	n.d.	2.0	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	24	1.0	1.1	n.d.	2.0	$1\ 54^{(5)}$	3	13%
Nitrate-Nitrite N, Total (mg/l)	0.02	24	-----	n.d.	n.d.	0.28	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	25	0.09	0.09	0.02	0.16	$0.143^{(5)}$	3	12%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	25	-----	n.d.	n.d.	0.05	-----	-----	-----
Suspended Solids, Total (mg/l)	4	25	19	19	5	51	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	$88^{(2)}$, $30^{(3)}$	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	3	n.d.	5	$340^{(2)}$, $16.7^{(3,4)}$	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	$130^{(2)}$, $5.3^{(3)}$	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	6	$7.6^{(2)}$, $0.3^{(3)}$	0, 1	0%, 25%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$734^{(2)}$, $96^{(3)}$	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$17.2^{(2)}$, $11\ 2^{(3)}$	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$86^{(2)}$, $3.3^{(3)}$	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	$1.4^{(2)}$	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	$0.051^{(3,4)}$	0	0
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	$585^{(2)}$, $65^{(3)}$	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	$20^{(2)}$, $5^{(3)}$	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	$5.4^{(2)}$	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	$1,400^{(2)}$, $6.3^{(3)}$		
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	4	$146^{(2,3)}$	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	1.1	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	21	-----	n.d.	n.d.	0.13	$760^{(2)}$, $76^{(3)}$	0	0%
Atrazine, Total (ug/l)***	0.05	23	1.51	1.11	0 23	4.21	$330^{(2)}$, $12^{(3)}$	0	0%
Metolachlor, Total (ug/l)***	0.05	22	0.21	0.13	n.d.	0.90	$390^{(2)}$, $100^{(3)}$	0	0%
Pesticide Scan (ug/l)****	0.05	4	-----				*****	0	0%
Atrazine			1.71	1.64	0 28	3 30			
Metolachlor			-----	n.d.	n.d.	0 90			
Metribuzin			-----	0.05	n.d.	0 20			
Profluralin			-----	n.d.	n.d.	0 59			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 23.6 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 130 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

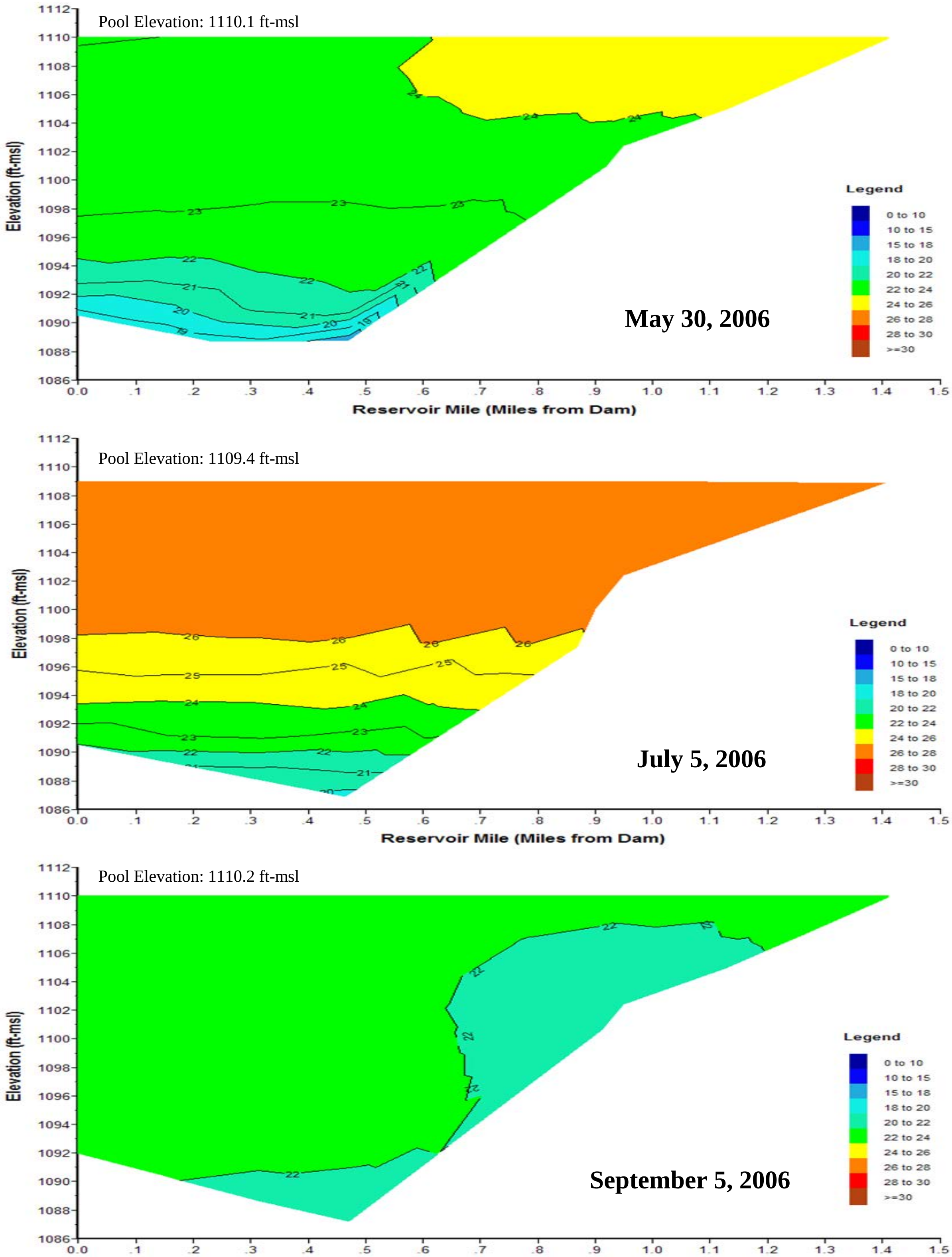

Plate 4. Longitudinal water temperature (°C) contour plots of Ed Zorinsky Reservoir based on depth-profile water temperatures measured at sites EZRLKND1, EZRLKML1, and EZRLKUP1 in May, July, and September 2006.

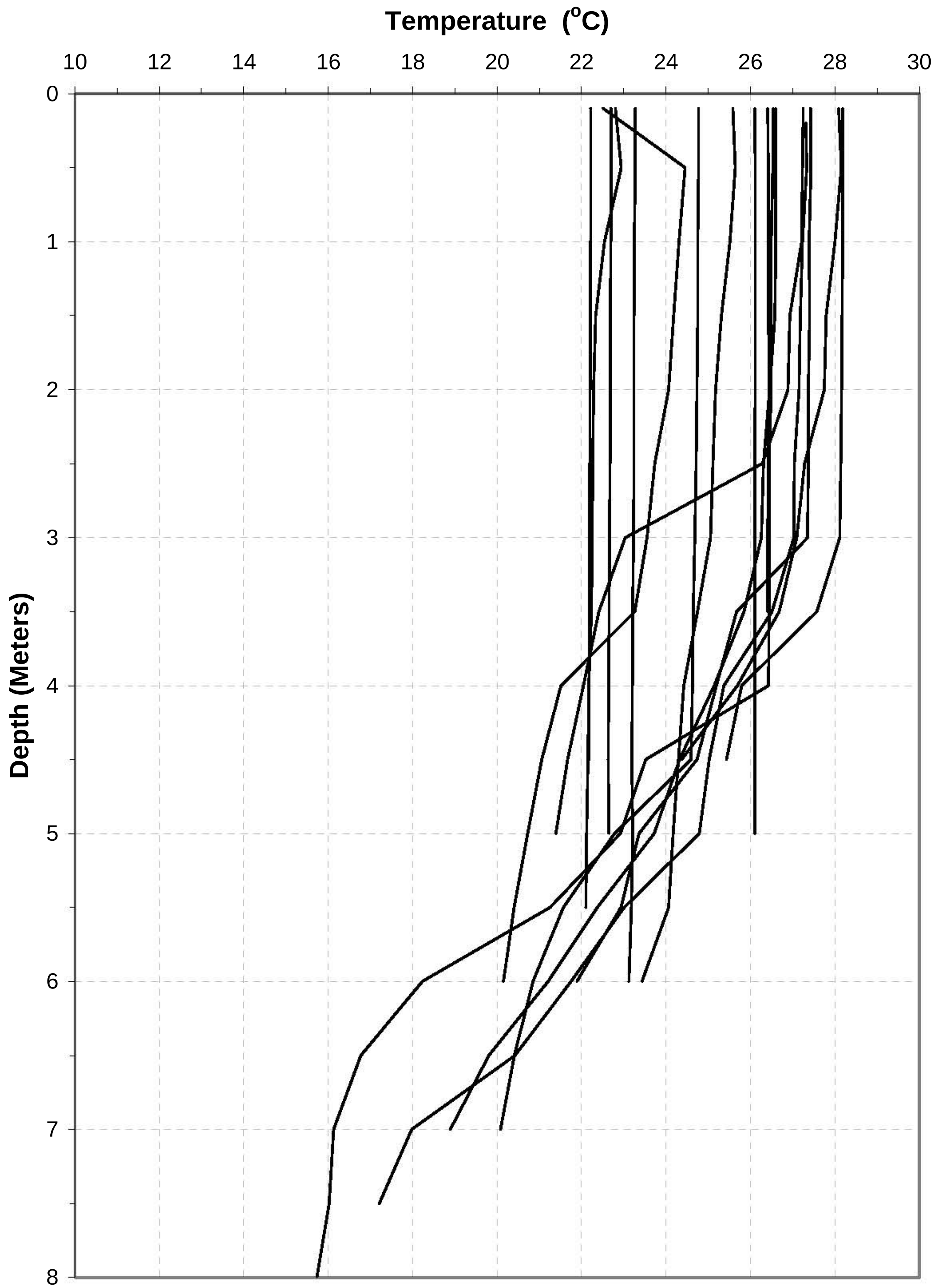

Plate 5. Temperature depth profiles for Ed Zorinsky Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., EZRLKND1) during the summer over the 5-year period of 2002 to 2006.

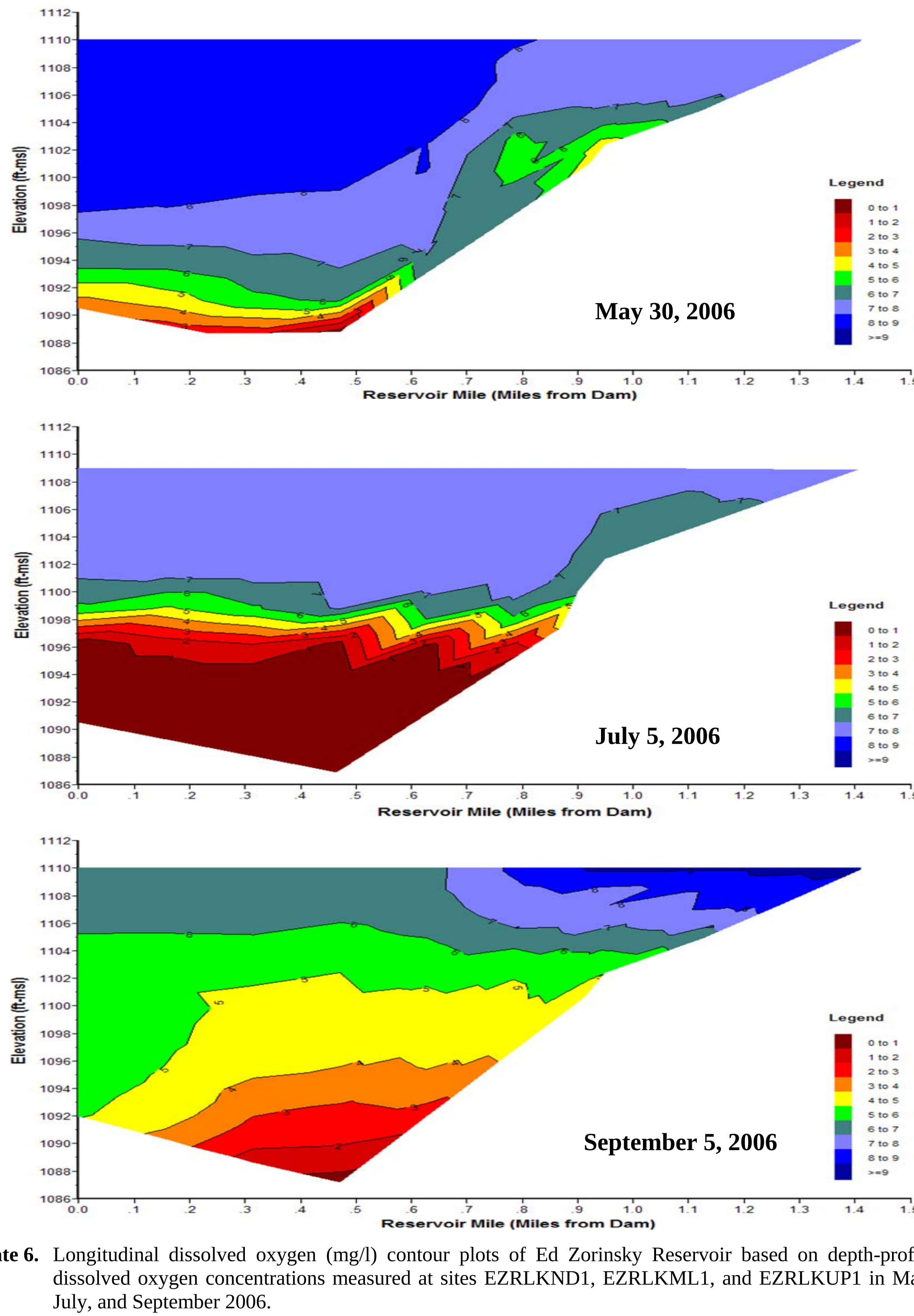

Plate 6. Longitudinal dissolved oxygen (mg/l) contour plots of Ed Zorinsky Reservoir based on depth-profile dissolved oxygen concentrations measured at sites EZRLKND1, EZRLKML1, and EZRLKUP1 in May, July, and September 2006.

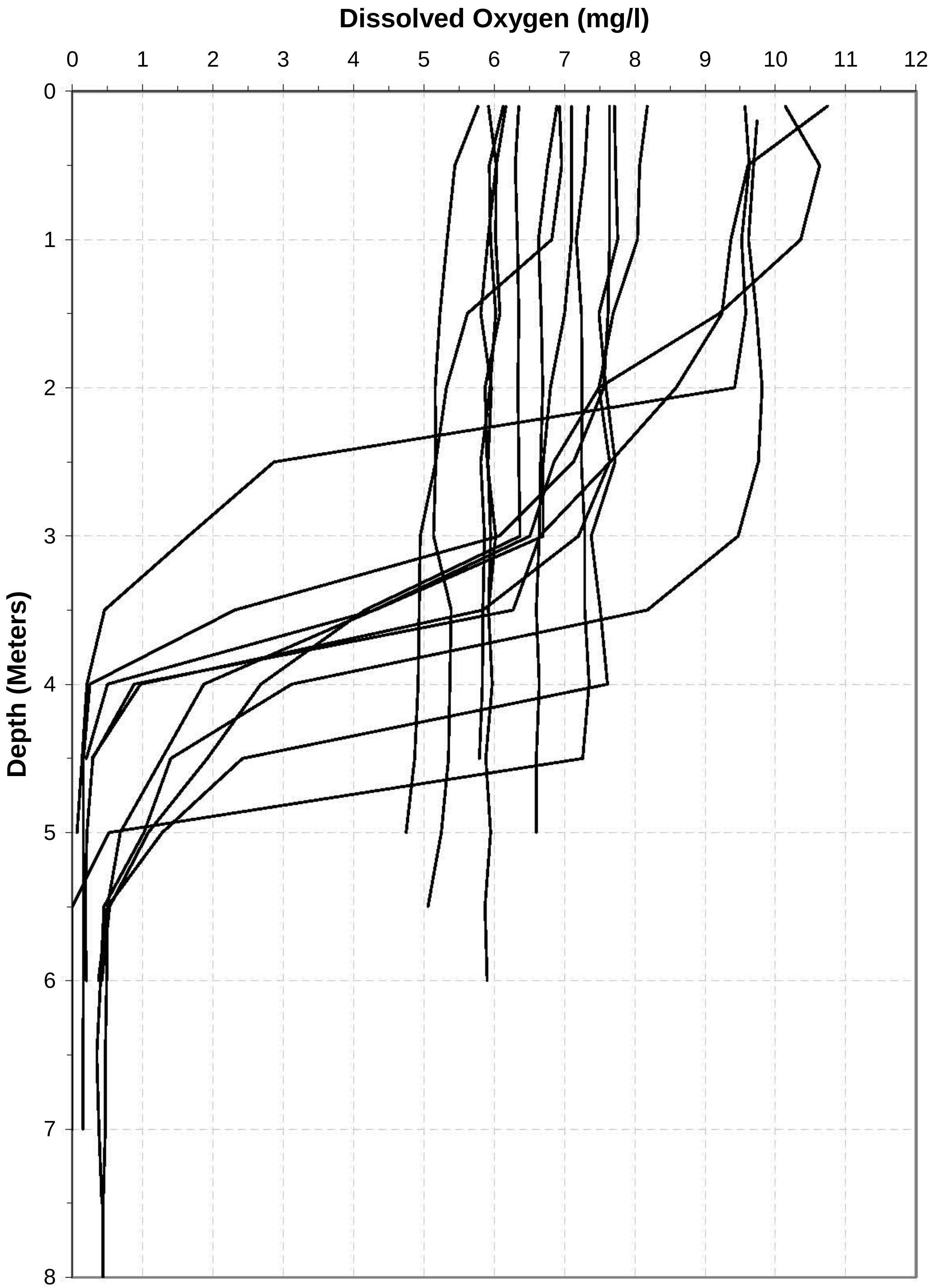

Plate 7. Dissolved oxygen depth profiles for Ed Zorinsky Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., EZRLKND1) during the summer over the 5-year period of 2002 to 2006.

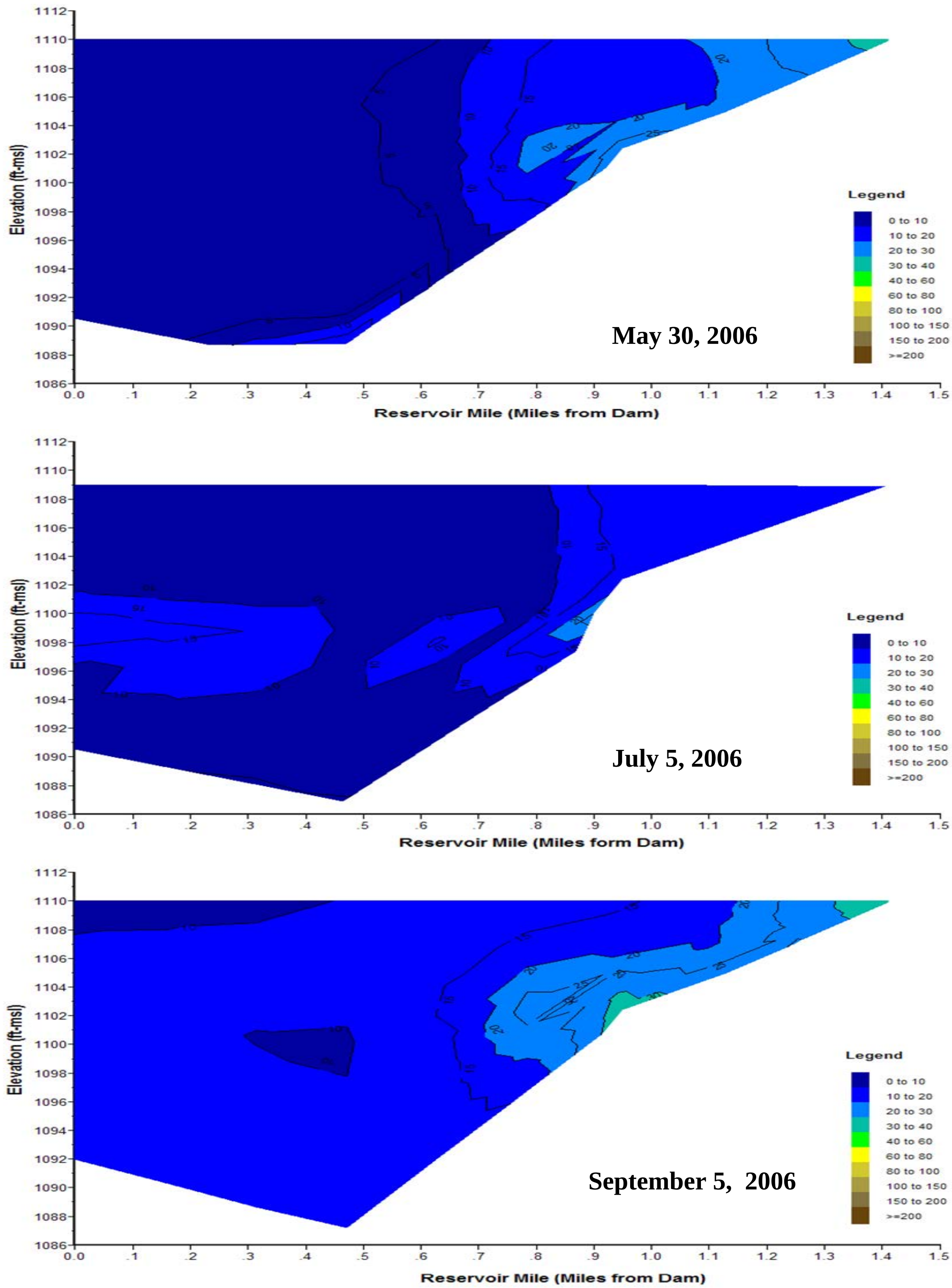

Plate 8. Longitudinal turbidity (NTU) contour plots of Ed Zorinsky Reservoir based on depth-profile turbidity levels measured at sites EZRLKND1, EZRLKML1, and EZRLKUP1 in May, July, and September 2006.

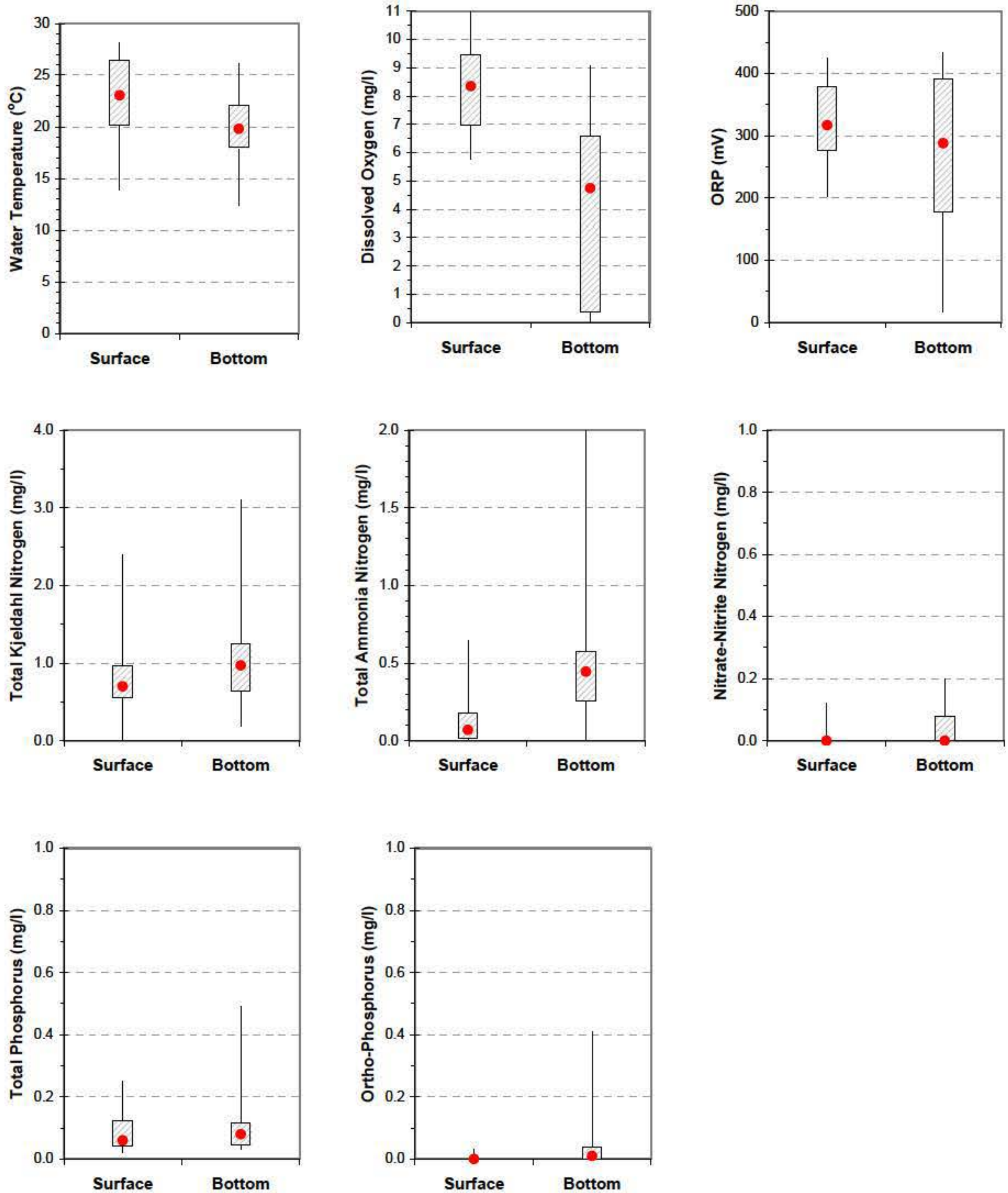

Plate 9. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Ed Zorinsky Reservoir at site EZRLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

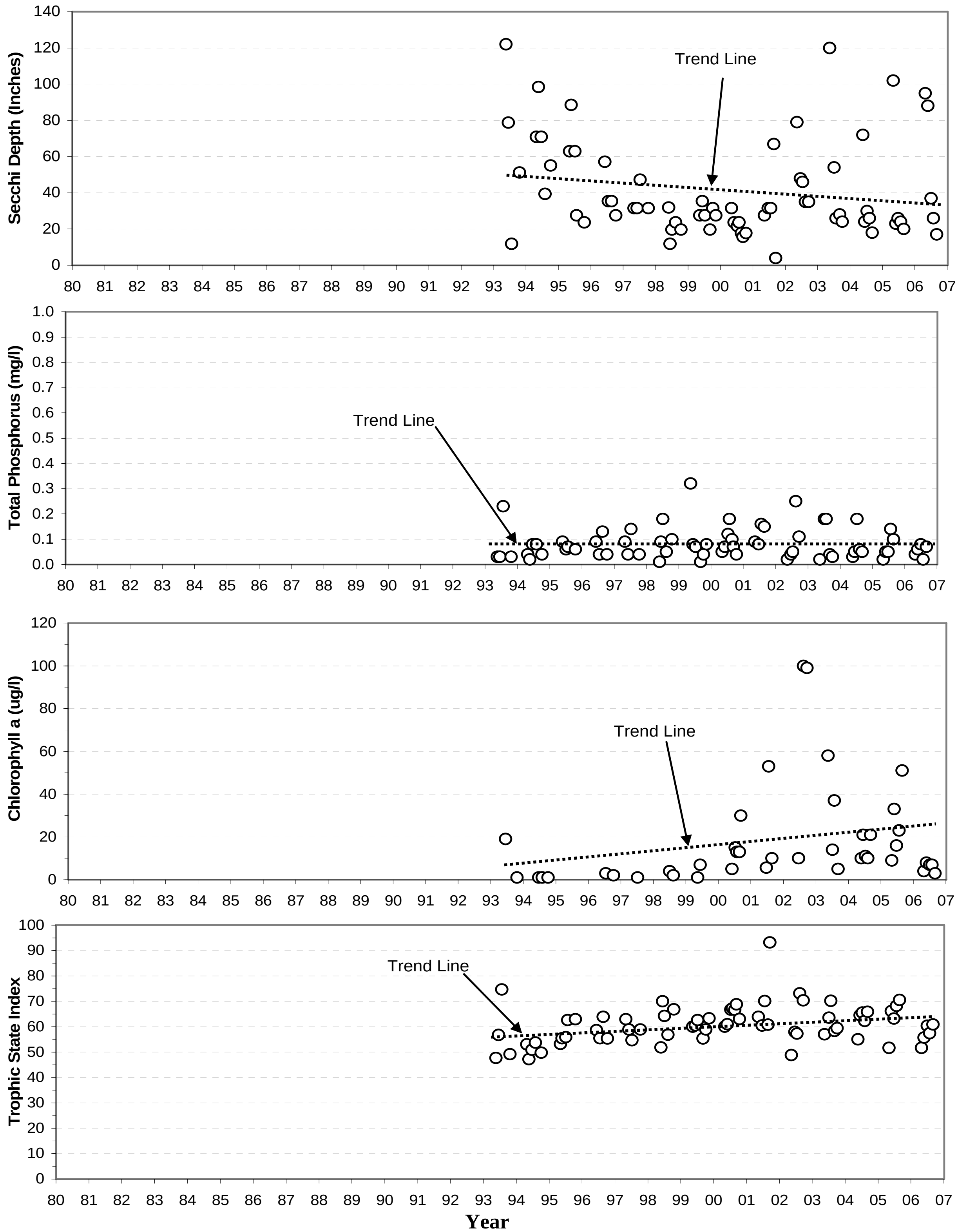

Plate 10. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Ed Zorinsky Reservoir at the near-dam, ambient site (i.e., site EZRLKND1) over the 27-year period of 1980 to 2006.

Plate 11. Summary of runoff water quality conditions monitored in the Boxelder Creek inflow to Ed Zorinsky Reservoir at monitoring site EZRNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	3	1,663	1,700	1,058	2,230	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	133	147	79	169	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	-----	0.33	n.d.	1.40	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	17	4.3	3.3	0.6	11.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	17	0.99	0.71	0.36	3.20		-----	-----
Phosphorus, Total (mg/l)	0.01	17	2.42	1.50	0.04	9.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	17	2,554	1,420	80	9,620	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	17	-----	0.08	n.d.	0.54	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	17	3.52	0.60	n.d.	33.30	330(2), 12(3)	0, 1	0%, 6%
Metolachlor, Total (ug/l)***	0.05	17	0.83	0.17	n.d.	4.20	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 12. Summary of water quality conditions monitored in Glenn Cunningham Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site GCRLKND1) from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	19	1121.3	1121.4	1120.5	1122.4	-----	-----	-----
Water Temperature (C)	0.1	223	22.0	23.5	11.2	27.5	32	0	0%
Dissolved Oxygen (mg/l)	0.1	222	5.5	5.8	n.d.	10.4	≥ 5.0	74	33%
Dissolved Oxygen (% Sat.)	0.1	222	63.9	70 5	n.d.	120.4	-----	-----	-----
Specific Conductance (umho/cm)	1	222	363	358	302	423	-----	-----	-----
pH (S.U.)	0.1	222	8.2	8.2	7.3	9.2	≥6.5 & ≤9.0	13	6%
Turbidity (NTUs)	0.1	117	23	18	12	75	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	151	380	381	250	467	-----	-----	-----
Secchi Depth (in.)	1	19	19	19	11	28	-----	-----	-----
Alkalinity, Total (mg/l)	7	37	175	180	101	206	-----	-----	-----
Ammonia, Total (mg/l)	0.01	24	0.27	0.24	n.d.	0.77	5.73 (1,2), 1.00 (1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	81	61	48	15	150	44(5)	43	53%
Chlorophyll *a* (ug/l) – Lab Determined	1	17	34	27	10	78	44(5)	5	29%
Hardness, Total (mg/l)	0.4	8	186	193	155	204	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	37	1.2	1.2	0.5	1.9	-----	-----	-----
Nitrogen, Total (mg/)	0.1	37	1.2	1.2	0.6	1.9	1.46(5)	12	32%
Nitrate-Nitrite N, Total (mg/l)	0.02	37	-----	n.d.	n.d.	0.12	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	37	0.14	0.12	0.06	0.65	0.134(5)	12	32%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	37	-----	n.d.	n.d.	0.06	-----	-----	-----
Suspended Solids, Total (mg/l)	4	37	18	14	n.d.	153	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	7	n.d.	8	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	11.2(2), 0.4(3)	0, 1	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,014(2), 132(3)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	25.0(2), 15.7(3)	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	131(2), 5.1(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	817(2), 91(3)	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	10.7(2)	0	0%
Thallium (ug/l)	6	2	-----	n.d.	n.d.	n.d.	1,400(2), 6.3(3)	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	3.	205(2,3)	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	0.2	0.22	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	14	-----	n.d.	n.d.	0.10	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	16	1.53	1.56	0.55	2.29	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	15	-----	0.06	n.d.	0.46	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)****	0.05	4					*****	0	0%
Acetochlor			-----	n.d.	n.d.	0.30			
Atrazine			0.64	0.60	0.55	0.80			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 23.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 193 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 13. Summary of water quality conditions monitored in Glenn Cunningham Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site GCRLKML1) from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1121.3	1121.4	1120.3	1122.4	-----	-----	-----
Water Temperature (C)	0.1	167	21.9	23.3	12.0	27.9	32	0	0%
Dissolved Oxygen (mg/l)	0.1	167	7.1	7.5	0.1	12.5	≥ 5.0	27	16%
Dissolved Oxygen (% Sat.)	0.1	167	82.0	84.6	0.6	140.8	-----	-----	-----
Specific Conductance (umho/cm)	1	167	355	352	299	419	-----	-----	-----
pH (S.U.)	0.1	167	8.4	8.4	7.5	9.2	≥6.5 & ≤9.0	5	3%
Turbidity (NTUs)	0.1	83	30.5	24.5	11.6	77.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	109	384	383	300	461	-----	-----	-----
Secchi Depth (in.)	1	18	18	18	9	27	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	60	71	78	23	141	44(1)	44	73%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Nutrient criteria.

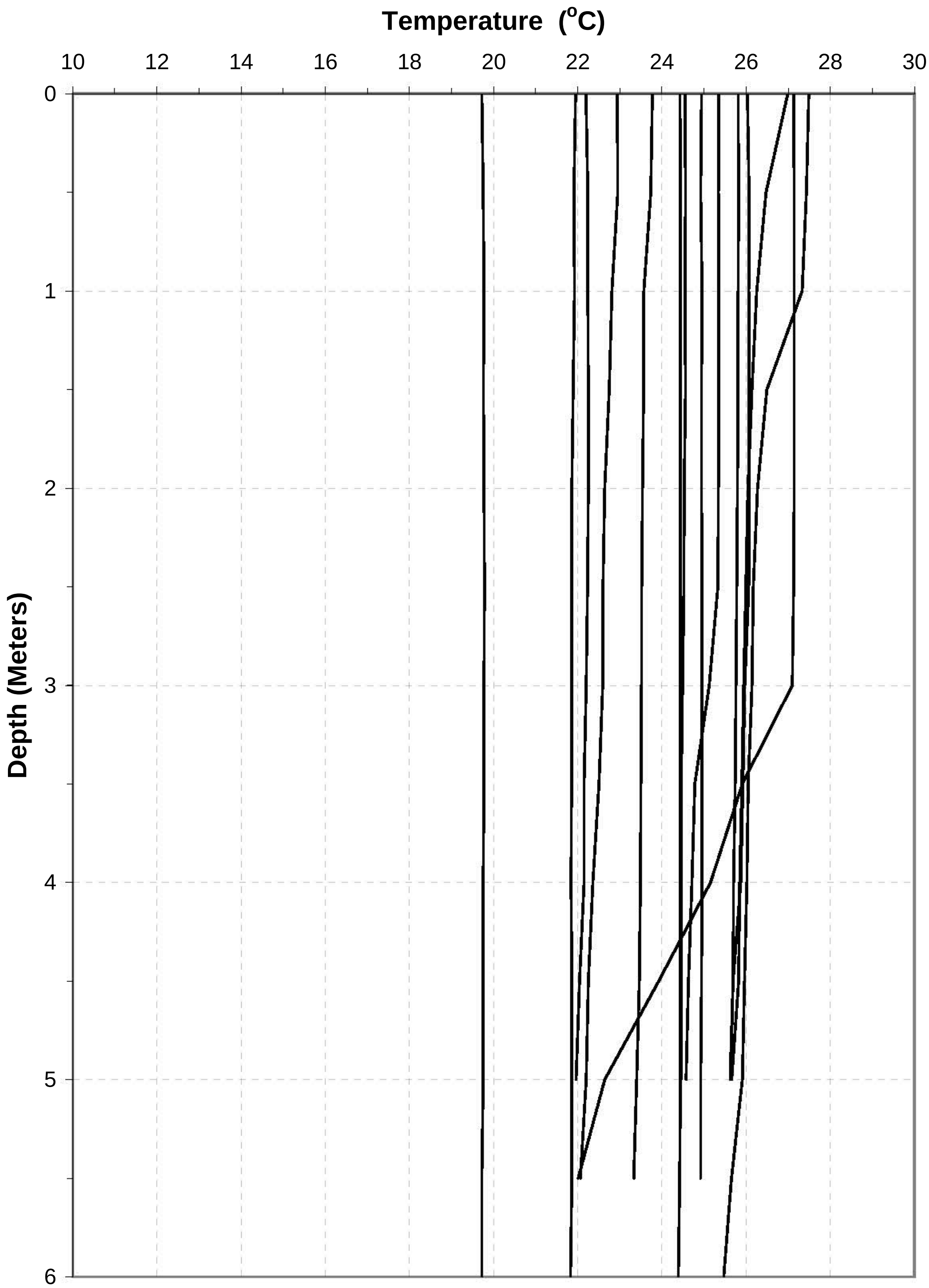

Plate 14. Temperature depth profiles for Glen Cunningham Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., GCRLKND1) during the summer over the 4-year period of 2002 to 2005.

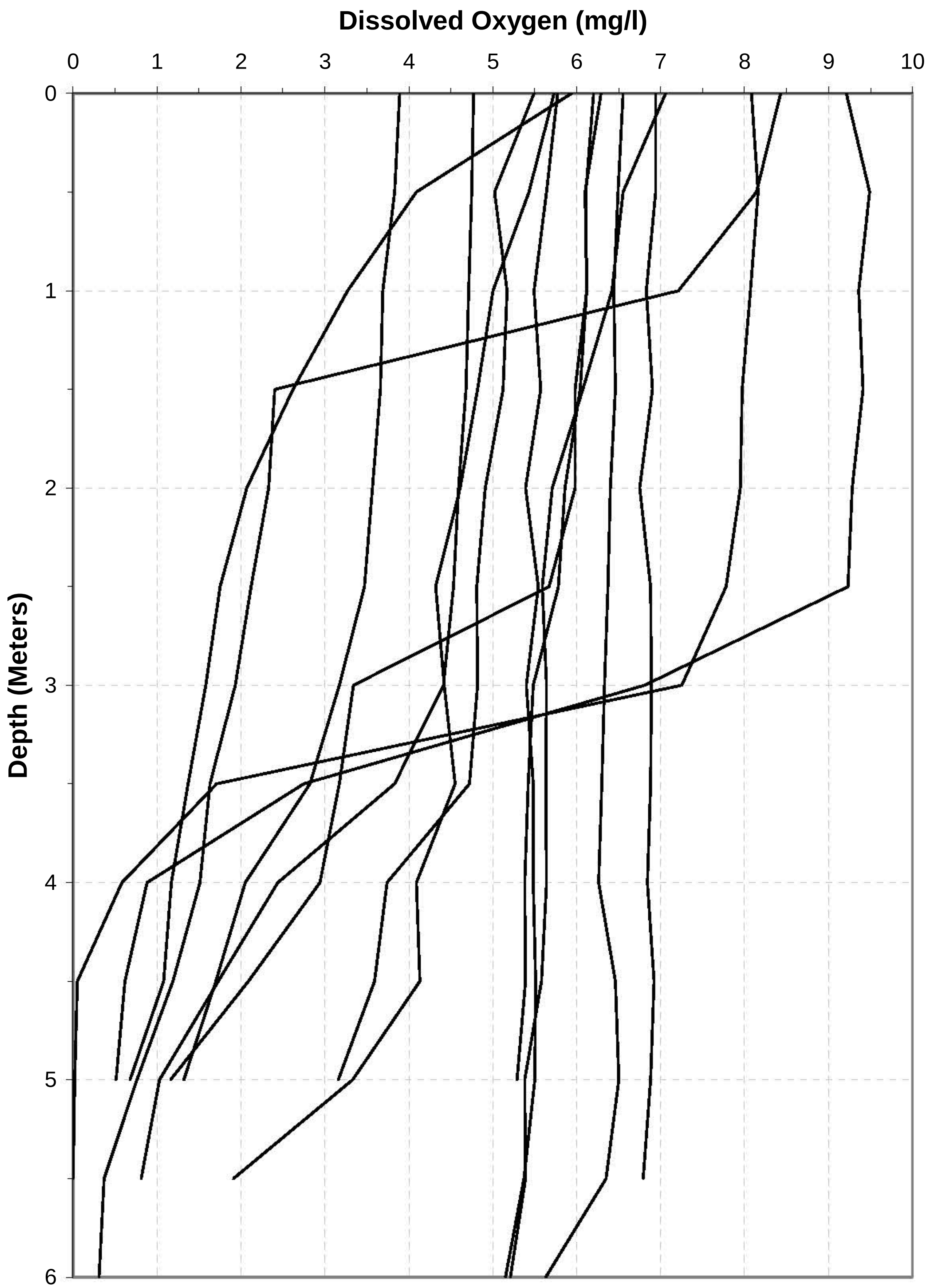

Plate 15. Dissolved oxygen depth profiles for Glen Cunningham Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., GCRLKND1) during the summer over the 4-year period of 2002 to 2005.

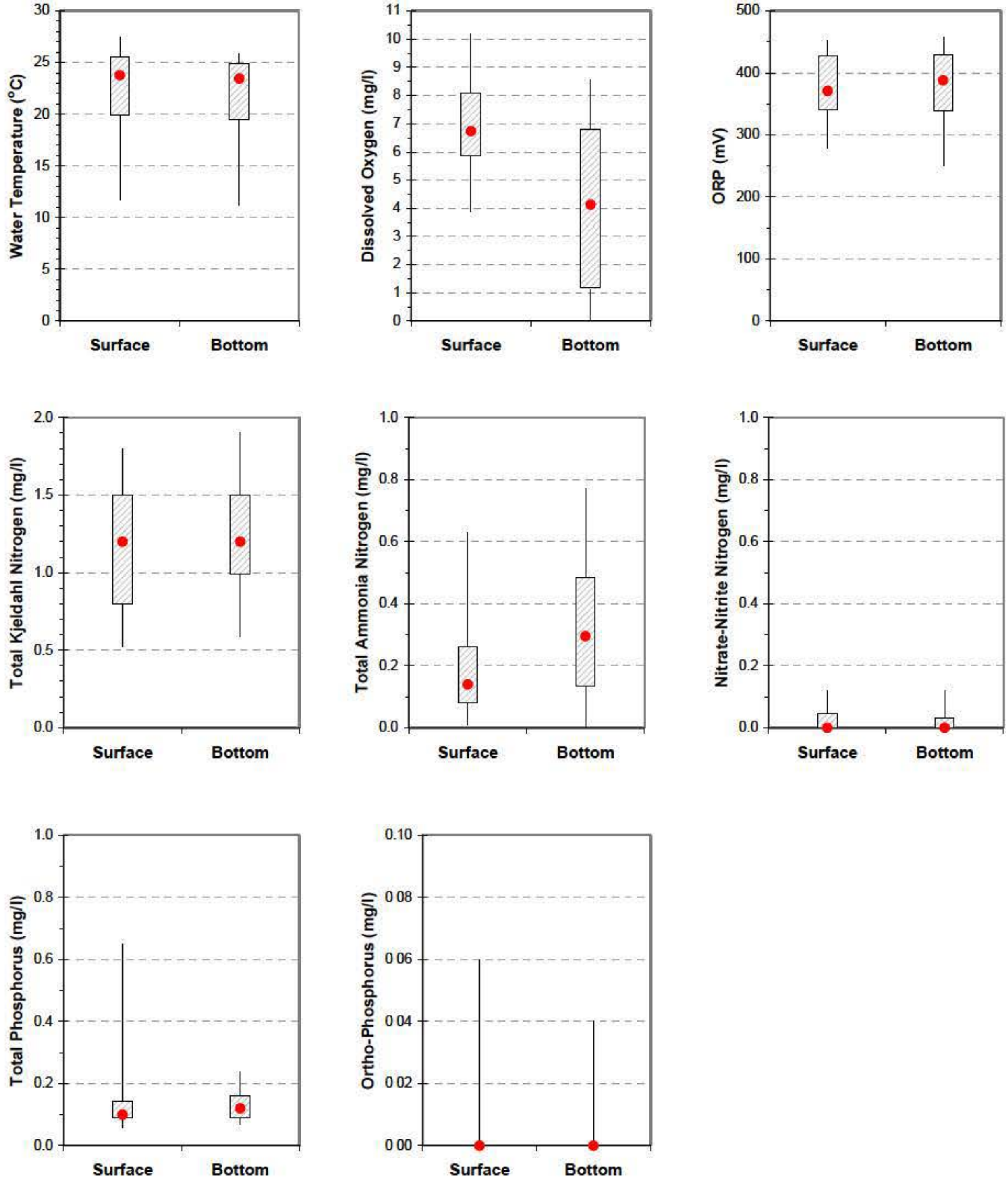

Plate 16. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Glenn Cunningham Reservoir at site GCRLKND1 during the summer months of 2002 through 2005. (Box plots display minimum, 25[th] percentile, 75[th] percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

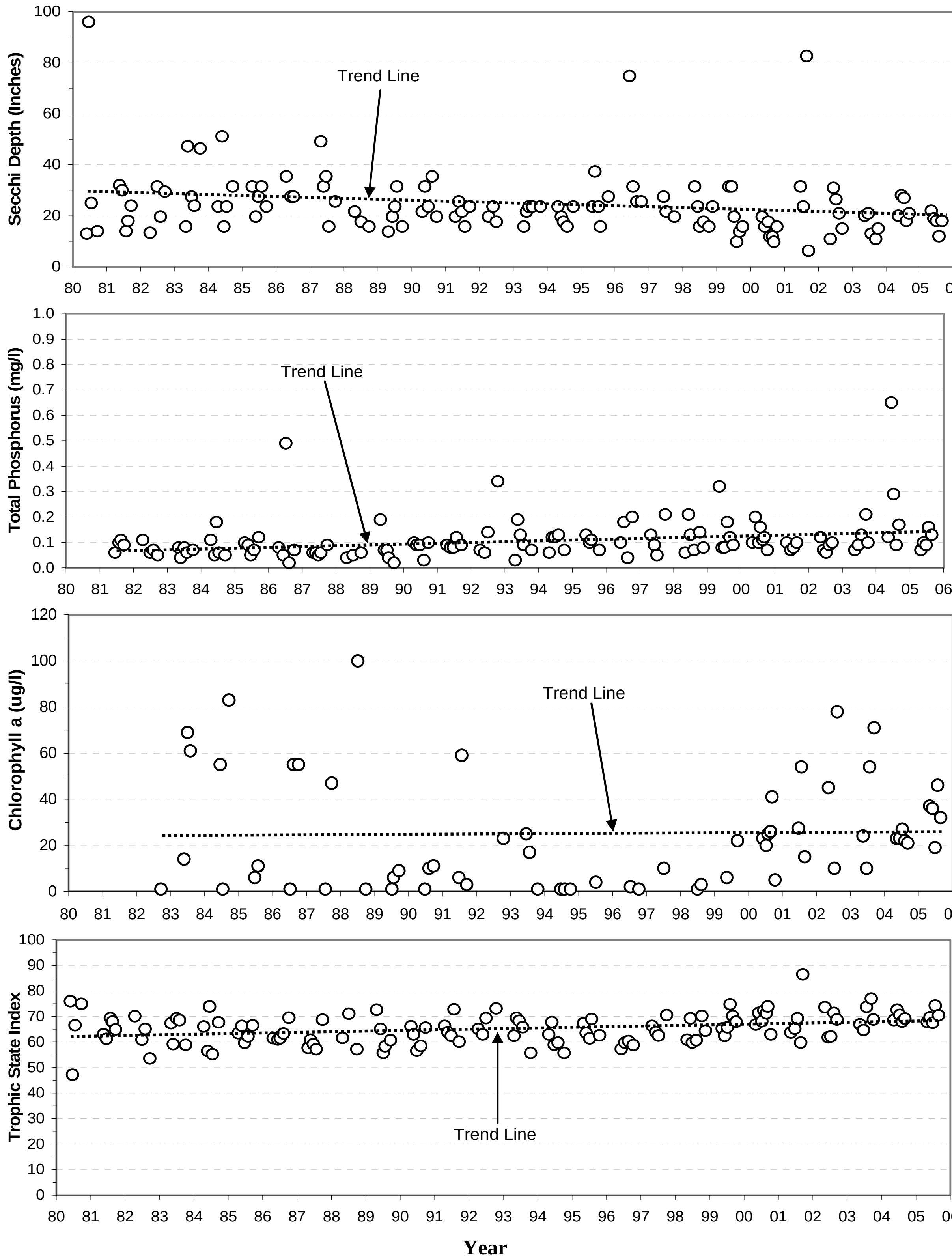

Plate 17. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Glenn Cunningham Reservoir at the near-dam, ambient site (i.e., site GCRLKND1) over the 26-year period of 1980 to 2005.

Plate 18. Summary of runoff water quality conditions monitored in the Knight Creek inflow to Glenn Cunningham Reservoir at monitoring site GCRNFNRT1 during the period 2002 through 2006.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	188	188	166	210	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	241	265	79	350	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	-----	0.43	n.d.	1.80	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	15	9.5	6.8	0.7	27.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	15	2.88	2.40	0.25	10.00		-----	-----
Phosphorus, Total (mg/l)	0.01	15	3.57	1.30	0.03	17.00	-----	-----	-----
Suspended Solids, Total (mg/l)	4	14	1,005	421	48	6,840	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	15	-----	0.10	n.d.	1.18	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	15	-----	0.83	n.d.	111.00	330(2), 12(3)	0, 4	0%, 27%
Metolachlor, Total (ug/l)***	0.05	15	-----	0.16	n.d.	33.30	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 19. Summary of runoff water quality conditions monitored in the east unnamed tributary inflow to Glenn Cunningham Reservoir at monitoring site GCRNFEST1 during the period 2002 through 2006.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	23	23	19	27	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	232	280	56	332	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	8	0.39	0.20	n.d.	1.40	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	14	1.9	1.2	0.4	8.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	14	2.47	0.88	0.17	10.00		-----	-----
Phosphorus, Total (mg/l)	0.01	14	1.57	0.70	0.03	8.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	14	749	244	35	5,130	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	14	-----	n.d.	n.d.	0.68	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	14	-----	0.46	n.d.	4.36	330(2), 12(3)	0, 0	0%
Metolachlor, Total (ug/l)***	0.05	14	-----	0.11	n.d.	2.80	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 20. Summary of water quality conditions monitored in Standing Bear Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site STBLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1103.8	1104.0	1101.9	1104.9	-----	-----	-----
Water Temperature (C)	0.1	283	22.0	22.5	12.8	28.5	32	0	0%
Dissolved Oxygen (mg/l)	0.1	283	6.2	7.1	n.d.	11.1	≥ 5.0	78	28%
Dissolved Oxygen (% Sat.)	0.1	259	73.3	84.8	n.d.	143.5	-----	-----	-----
Specific Conductance (umho/cm)	1	271	337	329	241	527	-----	-----	-----
pH (S.U.)	0.1	271	8.2	8.3	6.9	9.8	≥6.5 & ≤9.0	6	2%
Turbidity (NTUs)	0.1	153	21.6	16.9	3.0	78.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	198	301	330	-21	454	-----	-----	-----
Secchi Depth (in.)	1	25	28	27	13	61	-----	-----	-----
Alkalinity, Total (mg/l)	7	47	115	110	80	160	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	0.30	0.27	n.d.	1.50	4.71 (1,2), 0.91 (1,3)	0, 1	0%, 3%
Chlorophyll *a* (ug/l) – Field Probe	1	75	18	8	n.d.	100	16(5)	14	19%
Chlorophyll *a* (ug/l) – Lab Determined	1	21	24	20	5	71	16(5)	13	62%
Hardness, Total (mg/l)	0.4	10	114	109	95	146	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	49	0.9	0.9	n.d.	2.8	-----	-----	-----
Nitrogen, Total (mg/)	0.1	49	0.9	0.9	n.d.	2.8	1.54(5)	4	8%
Nitrate-Nitrite N, Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.22	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	49	0.08	0.06	0.02	0.37	0.143(5)	6	12%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	49	-----	n.d.	n.d.	0.12	-----	-----	-----
Suspended Solids, Total (mg/l)	4	48	13	10	n.d.	46	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	5	n.d.	6	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	6.4(2), 0.3(3)	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	635(2), 83(3)	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	14.6(2), 9.6(3)	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	71(2), 2.8(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	504(2), 56(3)	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	4.0(2)	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400(2), 6.3(3)	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	3	126(2,3)	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	21	-----	n.d.	n.d.	0.07	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	22	0.60	0.60	0.08	2.17	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	21	-----	n.d.	n.d.	0.19	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)****	0.05	4	-----				*****	0	0%
Atrazine			0.41	0.21	0.20	1.00			
Metolachlor			-----	n.d.	n.d.	0.10			
Profluralin			-----	n.d.	n.d.	0.49			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 22.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 109 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 21. Summary of water quality conditions monitored in Standing Bear Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site STBLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1103.8	1104.0	1101 9	1104.9	-----	-----	-----
Water Temperature (C)	0.1	238	22.1	22.9	11 5	29.0	32	0	0%
Dissolved Oxygen (mg/l)	0.1	229	6.7	7.4	0 1	10.9	≥ 5.0	39	17%
Dissolved Oxygen (% Sat.)	0.1	217	78.2	85.8	0.6	136.3	-----	-----	-----
Specific Conductance (umho/cm)	1	226	332	328	244	459	-----	-----	-----
pH (S.U.)	0.1	226	8.3	8.3	7 1	9.6	≥6.5 & ≤9.0	6	3%
Turbidity (NTUs)	0.1	130	26.2	21.2	4 1	187.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	169	362	381	4	501	-----	-----	-----
Secchi Depth (in.)	1	23	26	20	13	60	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	74	19	9	n.d.	112	16(1)	18	24%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Nutrient criteria.

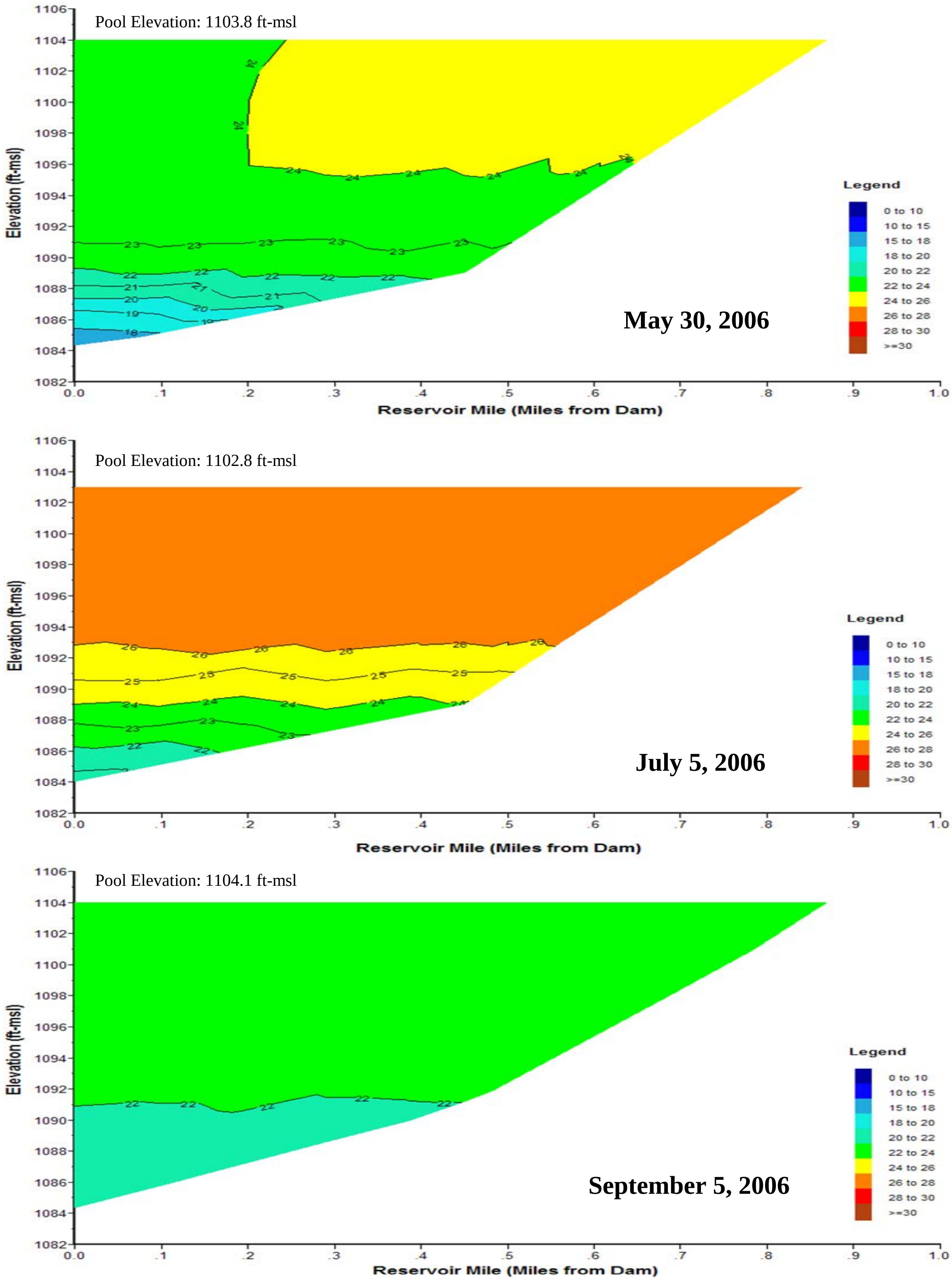

Plate 22. Longitudinal water temperature (°C) contour plots of Standing Bear Reservoir based on depth-profile water temperatures measured at sites STBLKND1 and STBLKML1 in May, July, and September 2006.

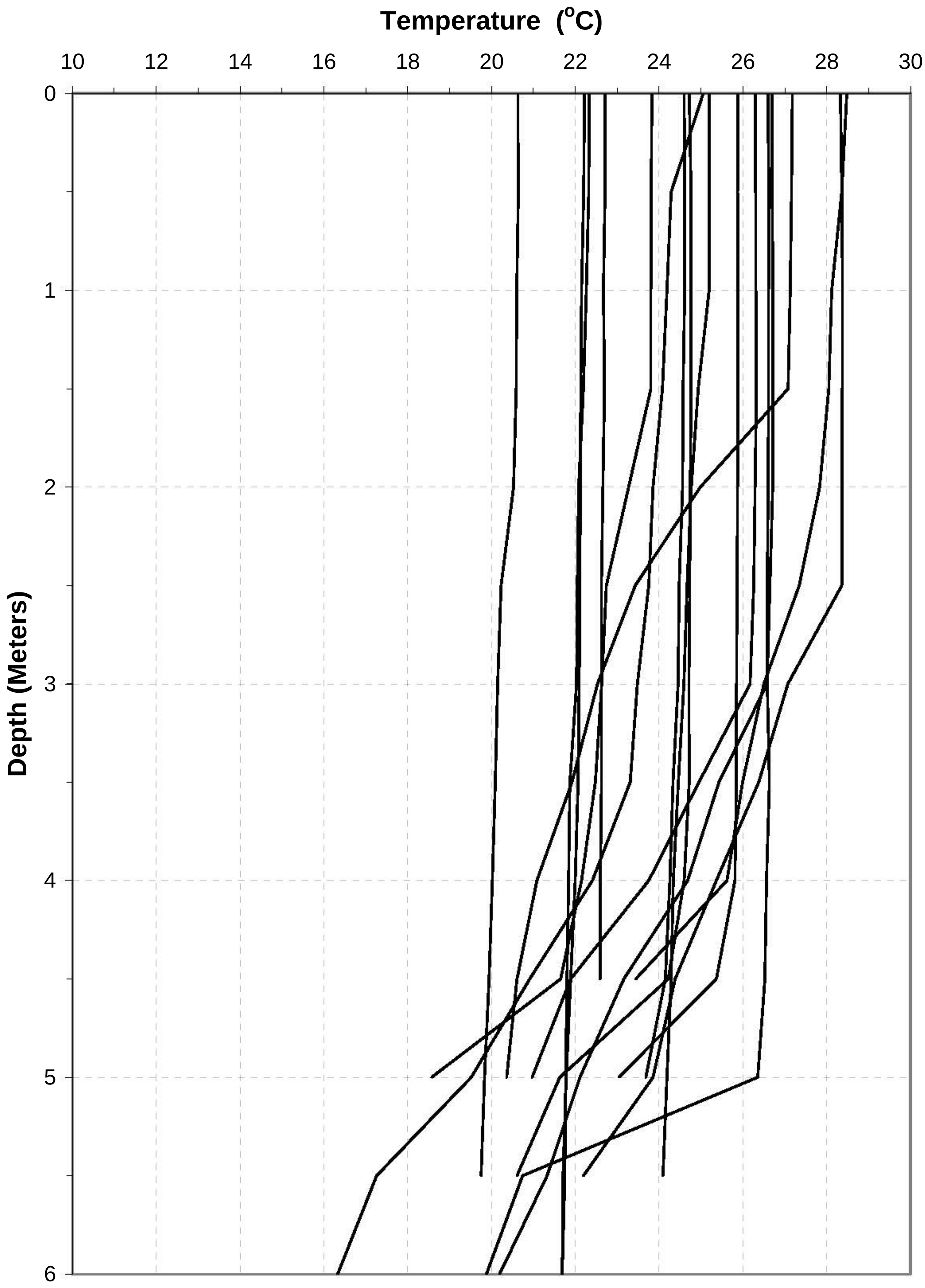

Plate 23. Temperature depth profiles for Standing Bear Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., STBLKND1) during the summer over the 5-year period of 2002 to 2006.

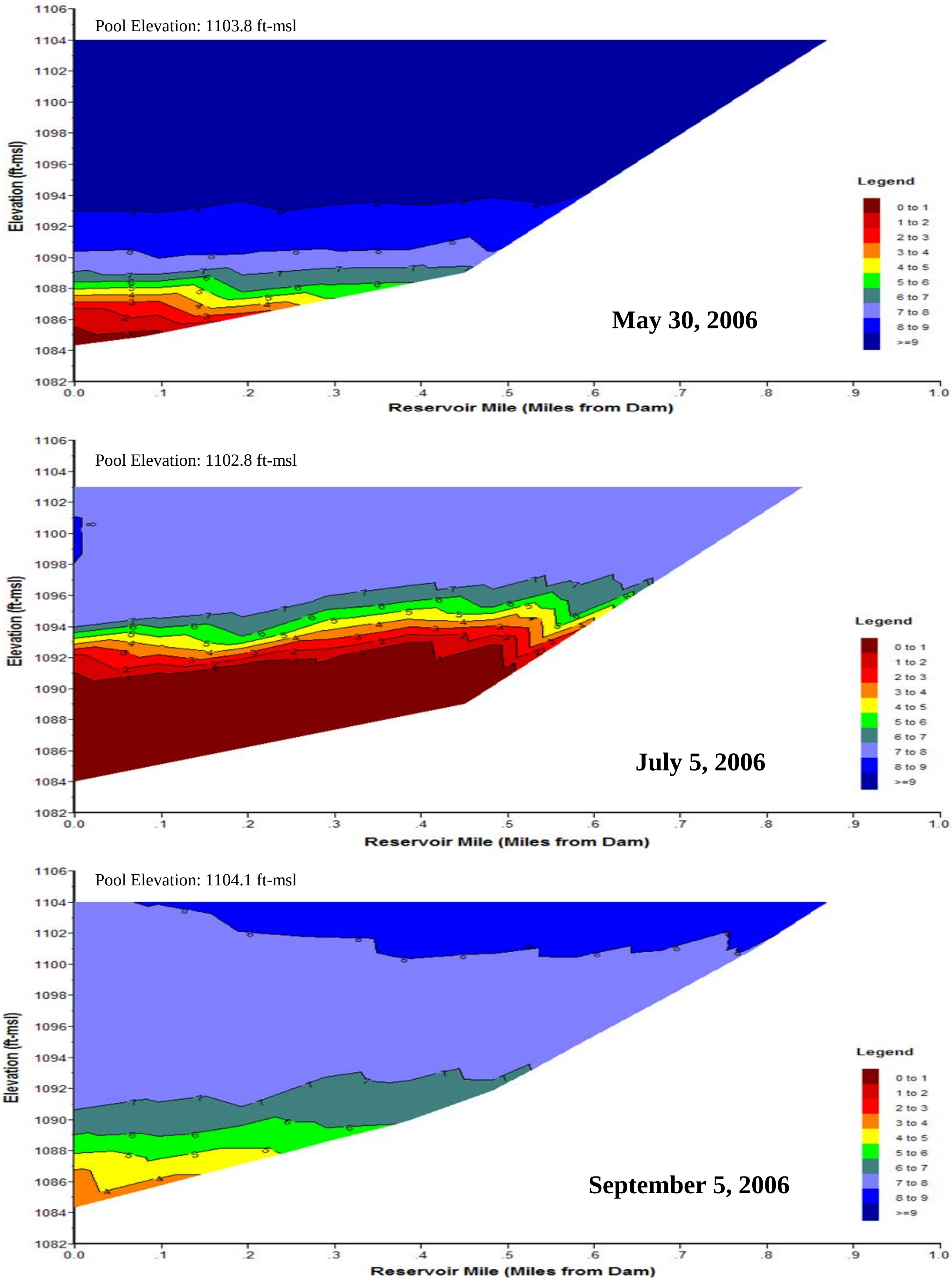

Plate 24. Longitudinal dissolved oxygen (mg/l) contour plots of Standing Bear Reservoir based on depth-profile dissolved oxygen concentrations measured at sites STBLKND1 and STBLKML1 in May, July, and September 2006.

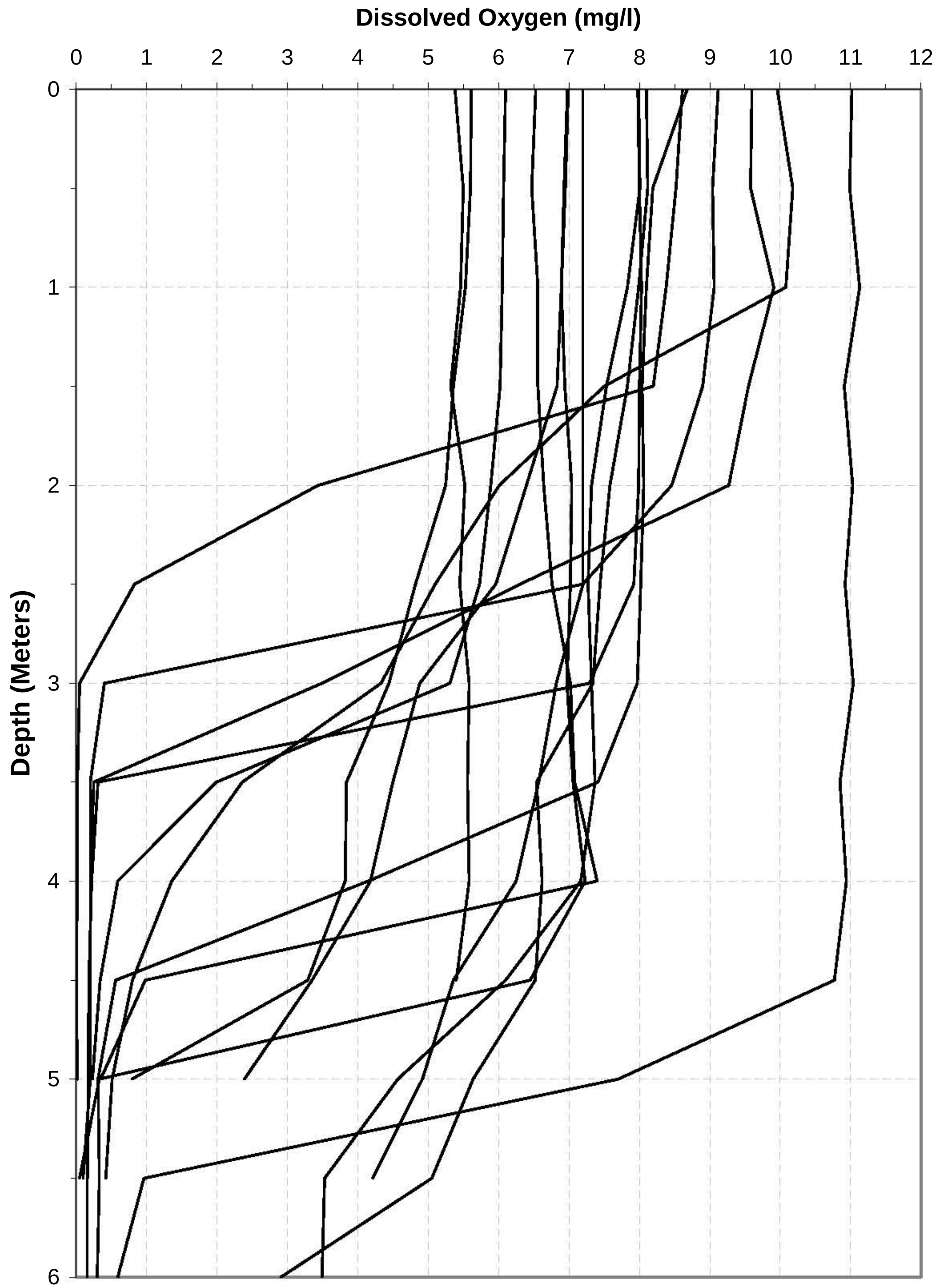

Plate 25. Dissolved oxygen depth profiles for Standing Bear Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., STBLKND1) during the summer over the 5-year period of 2002 to 2006.

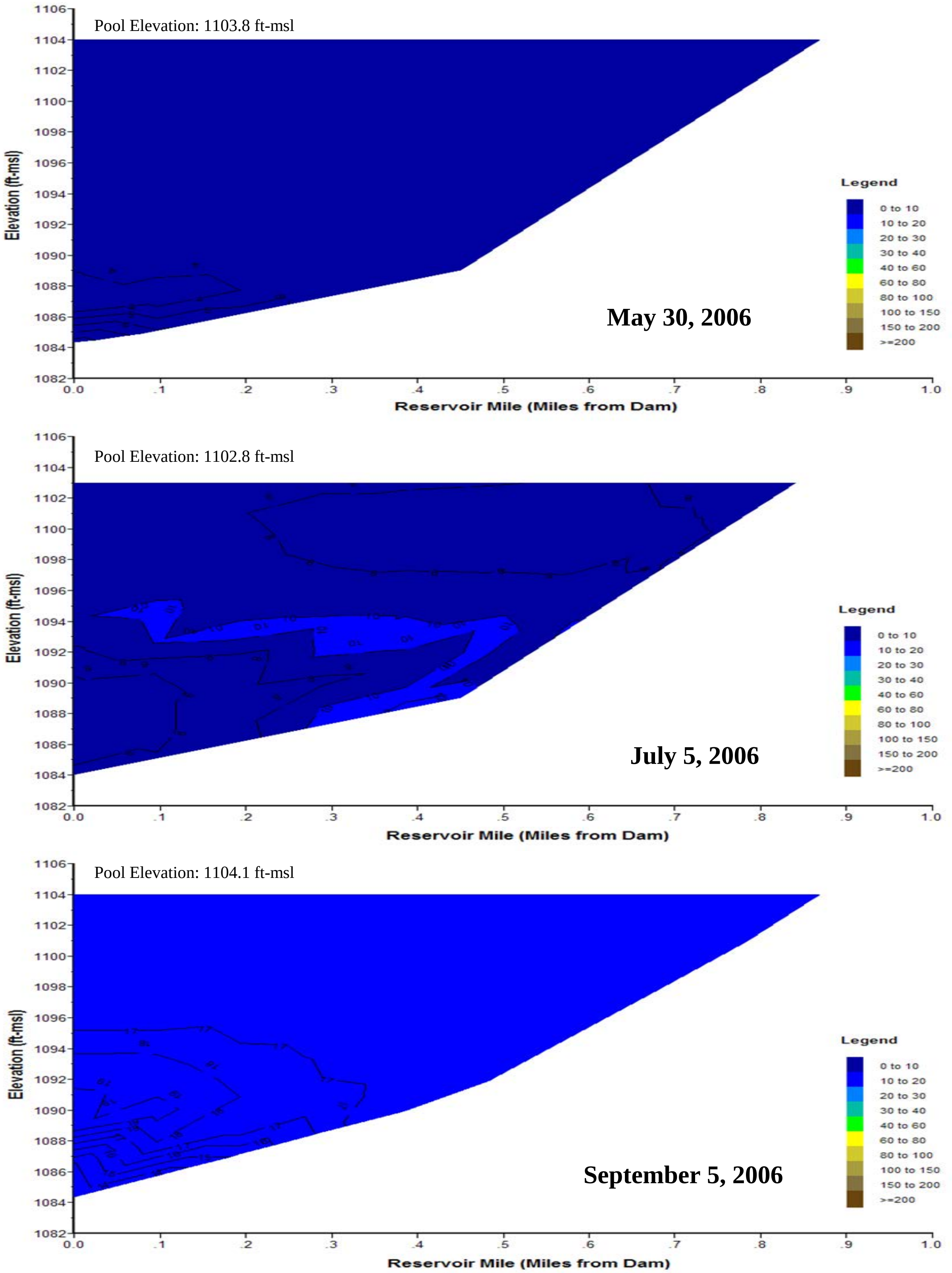

Plate 26. Longitudinal turbidity (NTU) contour plots of Standing Bear Reservoir based on depth-profile turbidity levels measured at sites STBLKND1 and STBLKML1 in May, July, and September 2006.

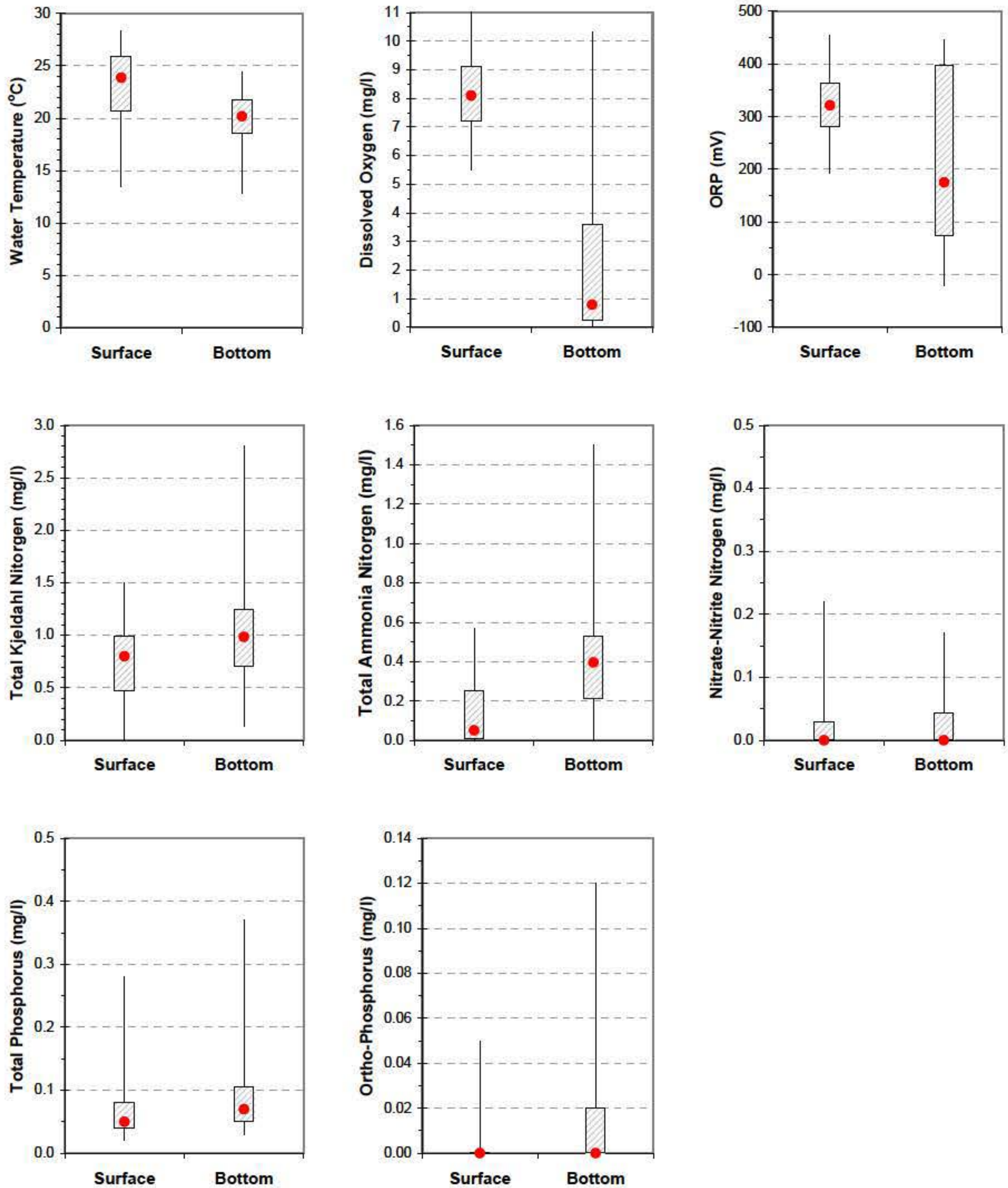

Plate 27. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Standing Bear Reservoir at site STBLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

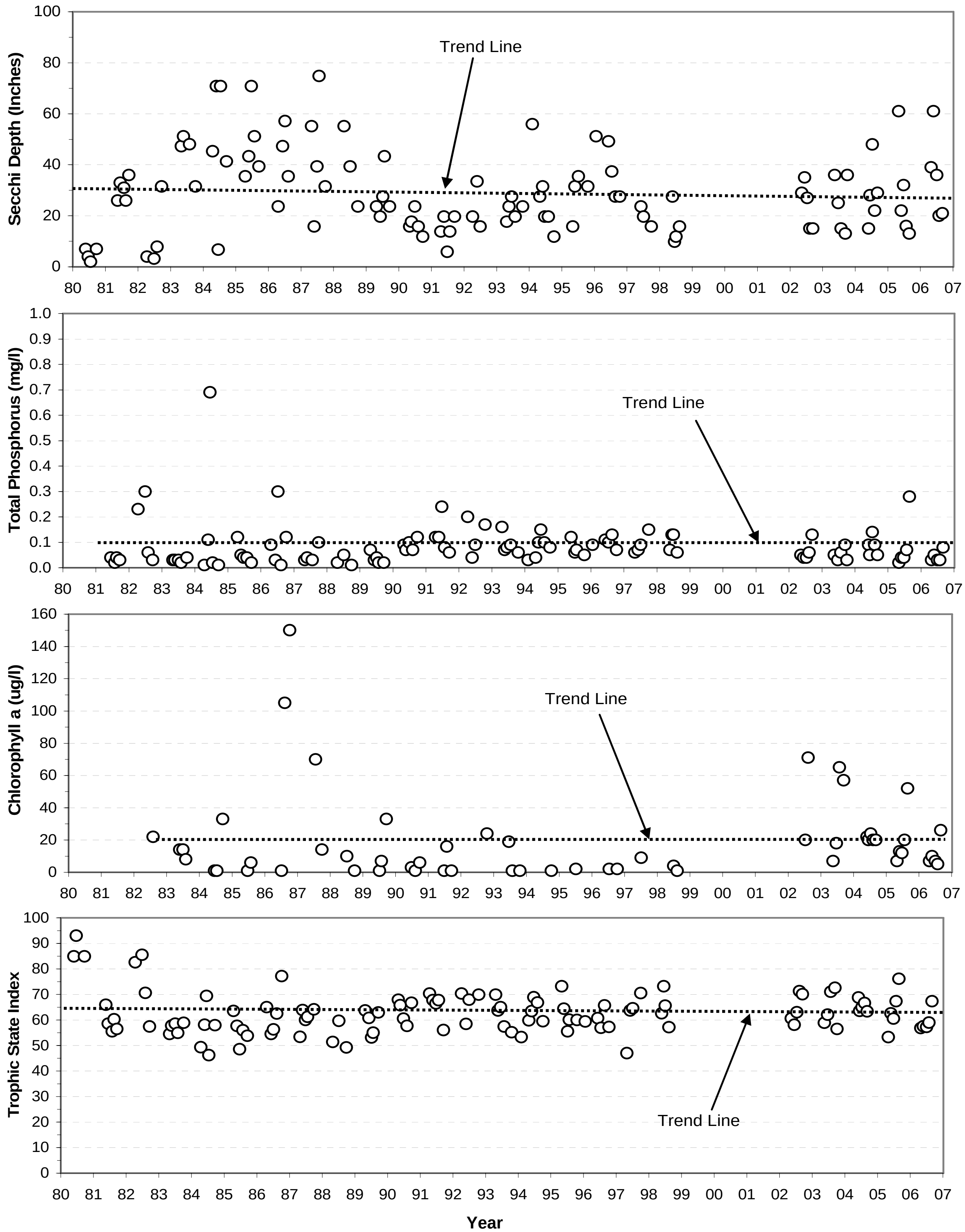

Plate 28. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Standing Bear Reservoir at the near-dam, ambient site (i.e., site STBLKND1) over the 27-year period of 1980 to 2006.

Plate 29. Summary of runoff water quality conditions monitored in the north tributary inflow to Standing Bear Reservoir at monitoring site STBNFNRT1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	3	81.3	100.0	23.0	121.0	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	77	95	29	110	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	-----	0.20	n.d.	1.20	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	16	1.4	1.3	0.1	3.2	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	16	0.26	0.13	n.d.	0.81		-----	-----
Phosphorus, Total (mg/l)	0.01	16	0.48	0.27	0.03	1.50	-----	-----	-----
Suspended Solids, Total (mg/l)	4	15	335	107	18	1,272	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	16	-----	0.06	n.d.	0.21	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	16	0.95	0.49	n.d.	3.22	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	16	0.20	0.11	n.d.	0.72	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 30. Summary of runoff water quality conditions monitored in the south tributary inflow to Standing Bear Reservoir at monitoring site STBNFSTH1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	31	31	16	46	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	74	68	40	113	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	-----	0.24	n.d.	1.30	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	15	1.3	1.2	0.3	2.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	15	0.82	0.33	0.01	7.70		-----	-----
Phosphorus, Total (mg/l)	0.01	15	0.49	0.41	0.06	0.83	-----	-----	-----
Suspended Solids, Total (mg/l)	4	14	316	248	24	704	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	16	-----	n.d.	n.d.	0.13	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	16	0.87	0.65	n.d.	2.82	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	16	-----	0.12	n.d.	0.75	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 31. Summary of water quality conditions monitored in Wehrspann Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site WEHLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1091.9	1092.0	1088.5	1095.4	-----	-----	-----
Water Temperature (C)	0.1	260	22.2	23.1	13.3	29.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	260	6.8	7.3	n.d.	11.1	≥ 5.0	53	20%
Dissolved Oxygen (% Sat.)	0.1	251	80.2	86 9	n.d.	142.9	-----	-----	-----
Specific Conductance (umho/cm)	1	251	395	378	300	569	-----	-----	-----
pH (S.U.)	0.1	251	8.4	8.5	7.1	9.1	≥6.5 & ≤9.0	6	2%
Turbidity (NTUs)	0.1	140	20.4	17.5	3.8	54.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	154	350	359	117	441	-----	-----	-----
Secchi Depth (in.)	1	25	24	20	11	57	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	125	120	96	192	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	-----	0.12	n.d.	0.67	3.20 (1,2), 0.63 (1,3)	0, 4	0%, 11%
Chlorophyll *a* (ug/l) – Field Probe	1	67	23	18	0	89	16(5)	35	52%
Chlorophyll *a* (ug/l) – Lab Determined	1	23	33	24	6	100	16(5)	17	74%
Hardness, Total (mg/l)	0.4	10	127	118	104	180	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	49	1.0	1.0	0.1	1.5	-----	-----	-----
Nitrogen, Total (mg/)	0.1	49	1.0	1.0	0.1	1.5	1.54(5)	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.14	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	49	0.14	0.12	n.d.	1.00	0.143(5)	15	31%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	49	-----	n.d.	n.d.	0.09	-----	-----	-----
Suspended Solids, Total (mg/l)	4	49	15	15	5	32	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	8	n.d.	10	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	6.9(2), 0.3(3)	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	678(2), 88(3)	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	15.7(2), 10.3(3)	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	77(2), 3.0(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	504(2), 56(3)	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	4.6(2)	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400(2), 6.3(3)	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	5	136(2,3)	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	0.5	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	23	-----	n.d.	n.d.	0.11	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	23	1.65	1.54	0.53	2.78	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	23	0.16	0.09	n.d.	0.89	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)****	0.05	4	-----				*****	0	0%
Atrazine			0.65	0.70	0.43	0.78			
Metribuzin			-----	0.05	n.d.	0.12			
Profluralin			-----	n.d.	n.d.	0.33			
Trifluralin			-----	n.d.	n.d.	0.21			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.5 and 23.1 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 109 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 32. Summary of water quality conditions monitored in Wehrspann Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site WEHLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	25	1091.9	1092.0	1088 5	1095.4	-----	-----	-----
Water Temperature (C)	0.1	206	21.9	22.4	13 1	28.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	205	7.2	7.5	n.d.	11.0	≥ 5.0	25	12%
Dissolved Oxygen (% Sat.)	0.1	193	83.4	86.0	n.d.	133.4	-----	-----	-----
Specific Conductance (umho/cm)	1	194	392	375	303	546	-----	-----	-----
pH (S.U.)	0.1	194	8.4	8.5	7.4	9.1	≥6.5 & ≤9.0	6	3%
Turbidity (NTUs)	0.1	100	19.4	18.4	5.6	47.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	124	360	385	80	429	-----	-----	-----
Secchi Depth (in.)	1	24	23	21	12	53	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	43	18	15	n.d.	43	16[(1)]	19	44%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [(1)] Nutrient criteria.

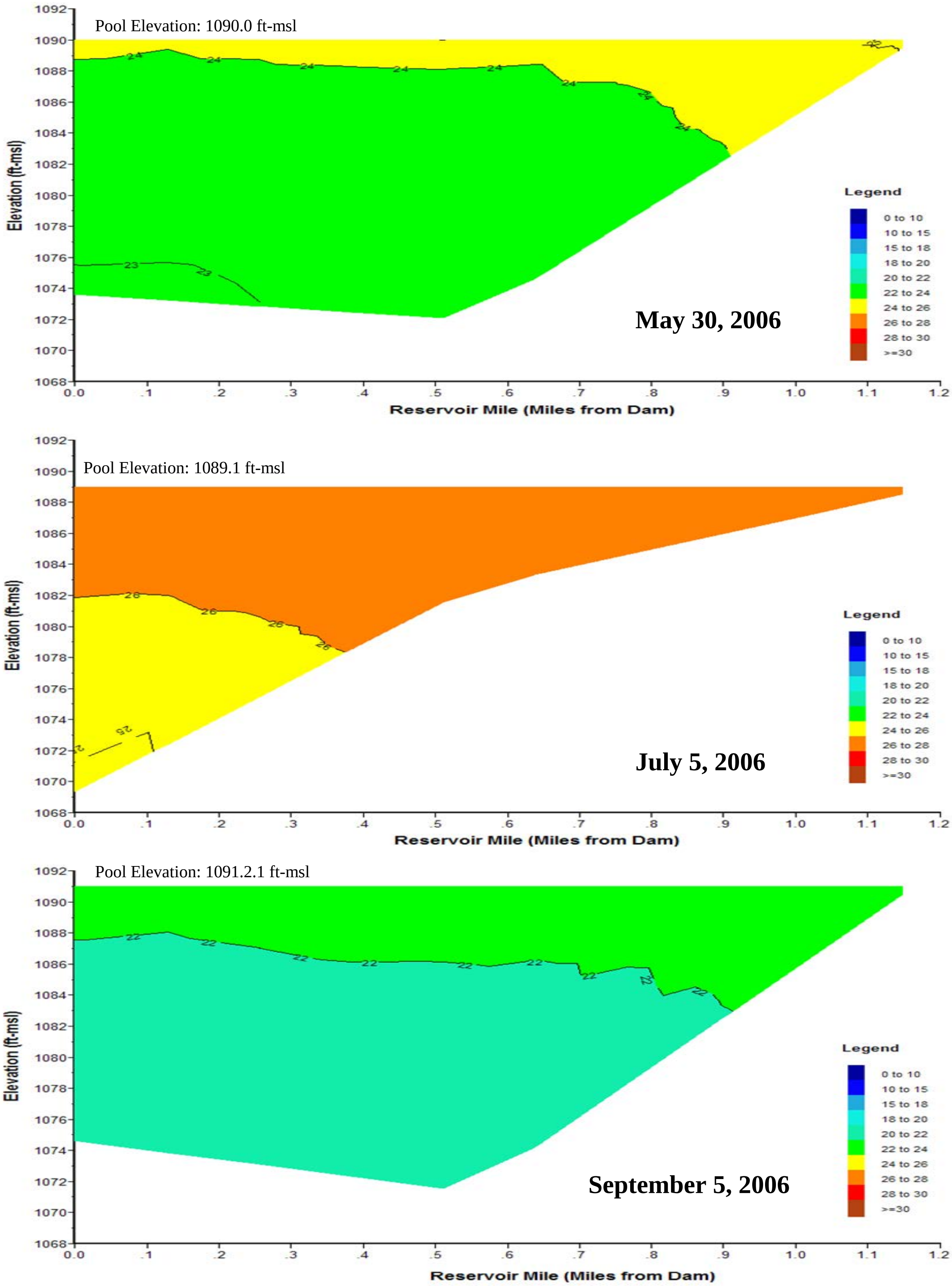

Plate 33. Longitudinal water temperature (°C) contour plots of Wehrspann Reservoir based on depth-profile water temperatures measured at sites WEHLKND1 and WEHLKML1 in May, July, and September 2006.

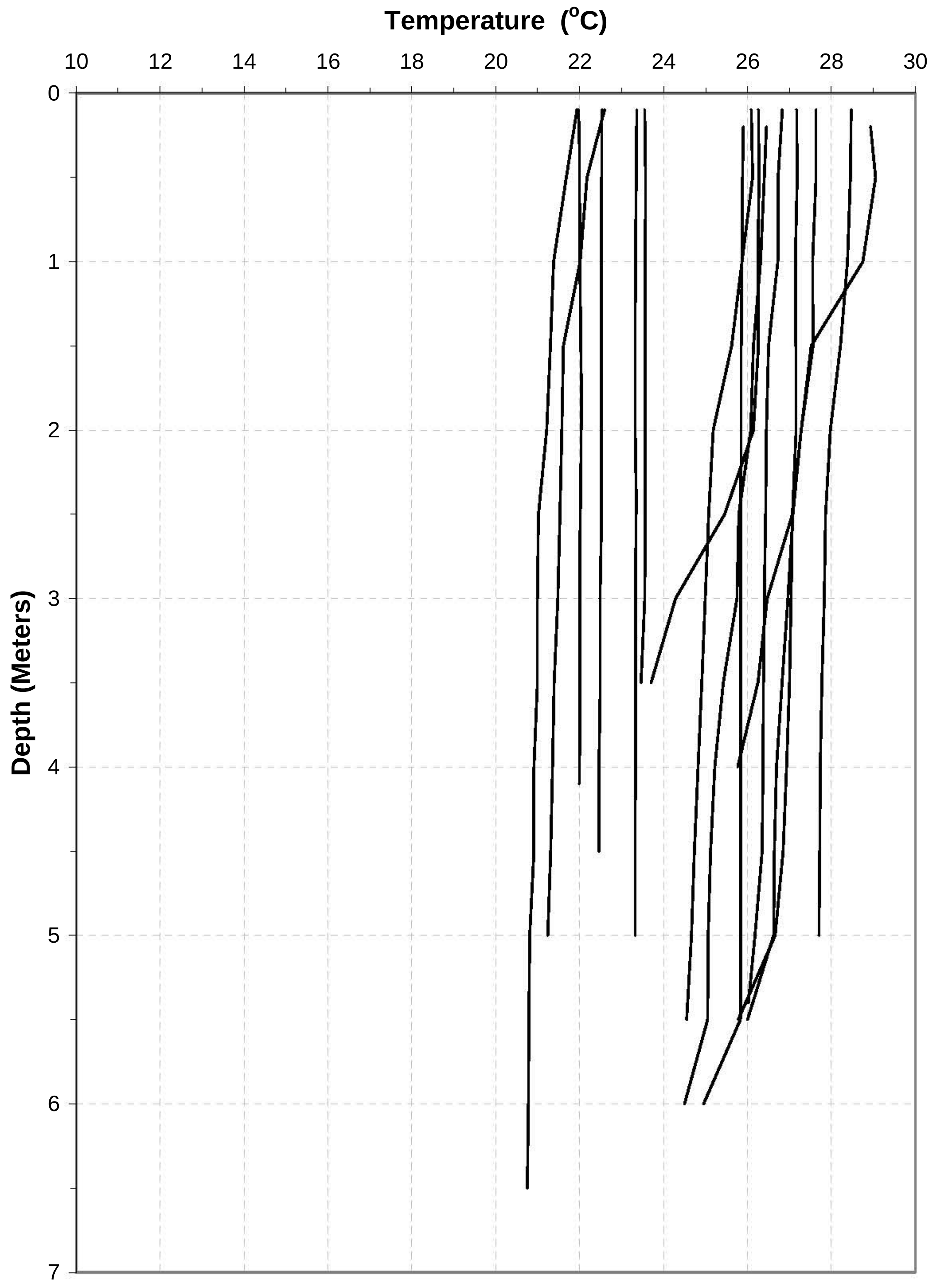

Plate 34. Temperature depth profiles for Wehrspann Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WEHLKND1) during the summer over the 5-year period of 2002 to 2006.

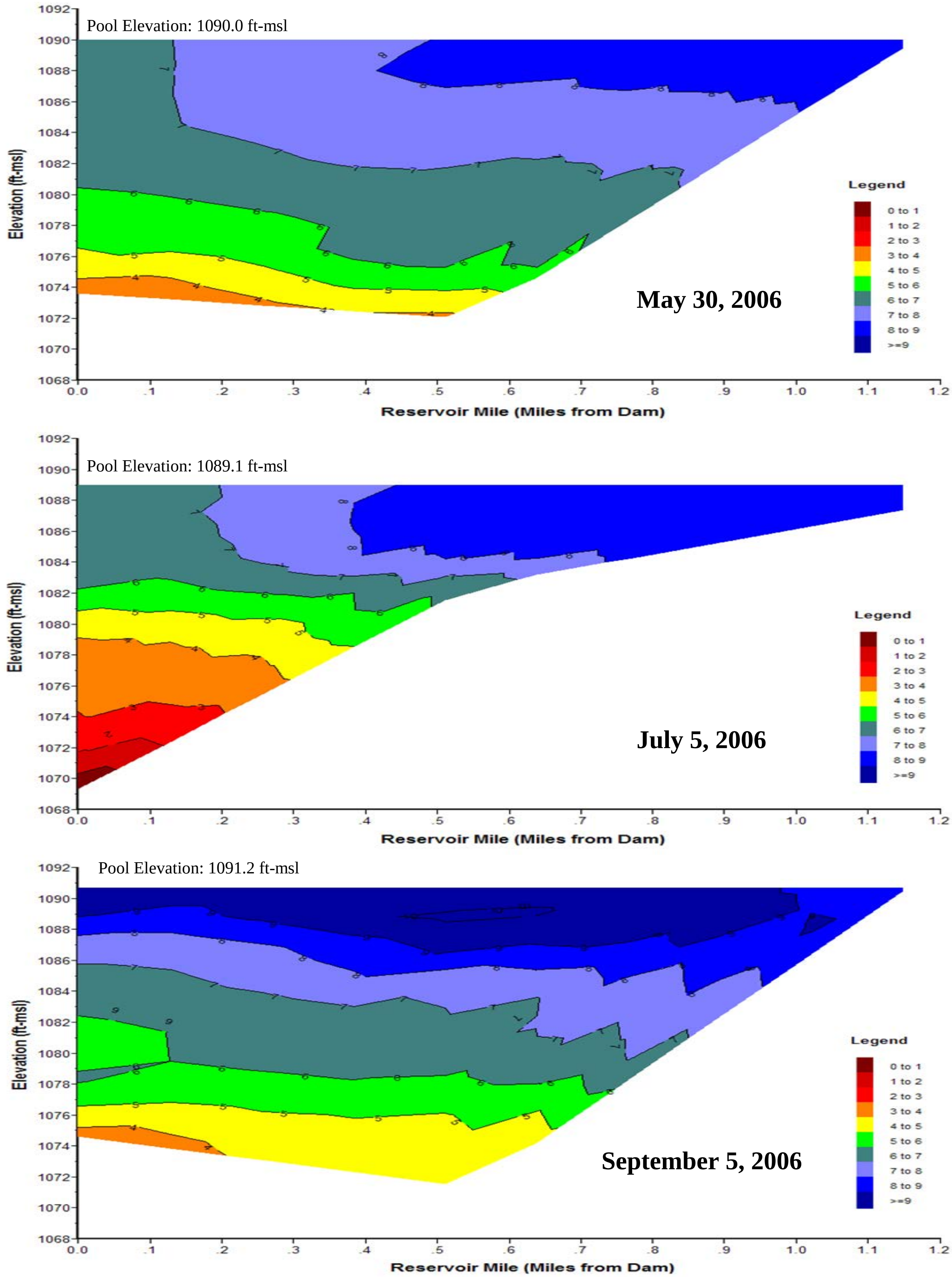

Plate 35. Longitudinal dissolved oxygen (mg/l) contour plots of Wehrspann Reservoir based on depth-profile dissolved oxygen concentrations measured at sites WEHLKND1 and WEHLKML1 in May, July, and September 2006.

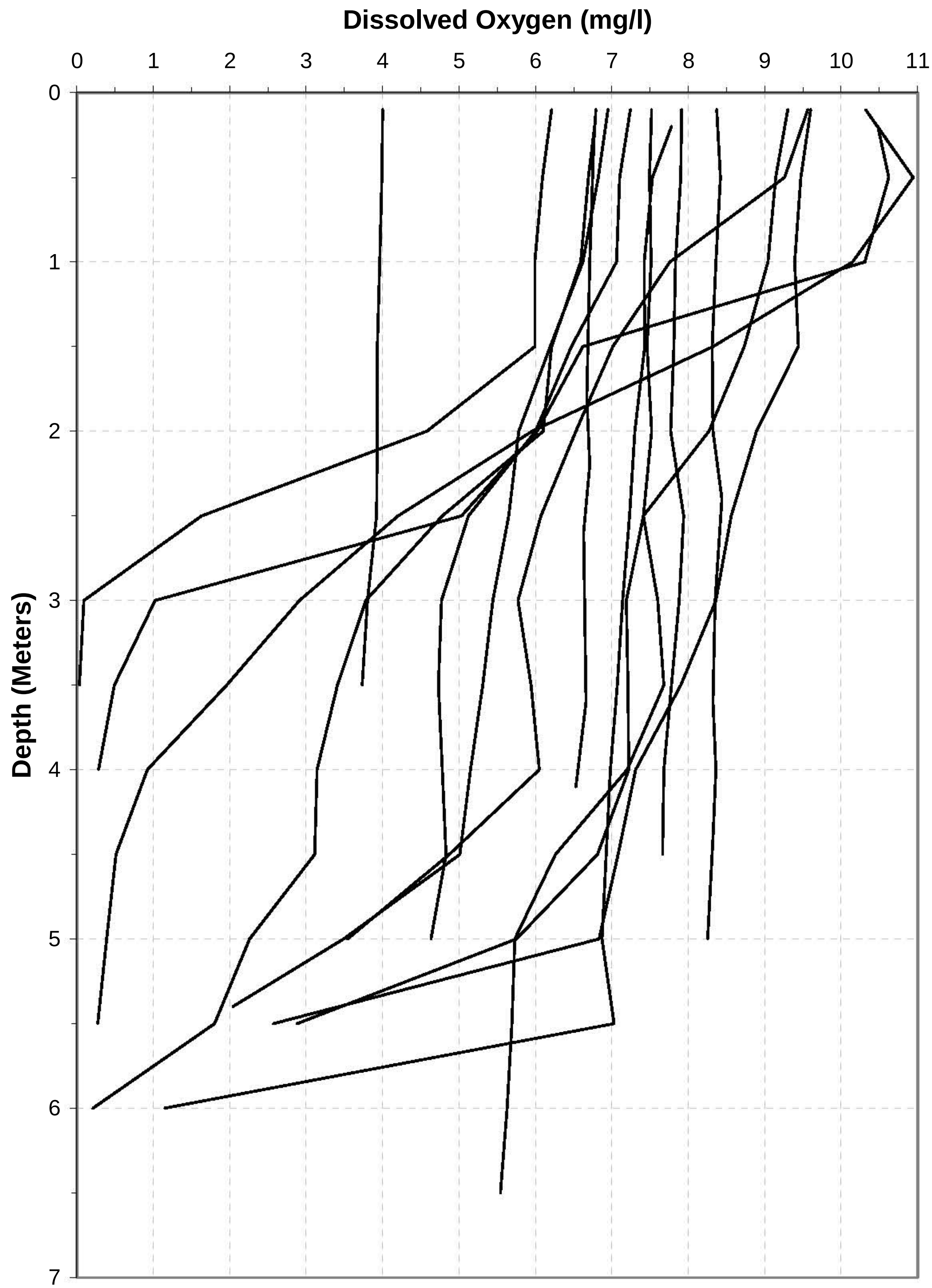

Plate 36. Dissolved oxygen depth profiles for Wehrspann Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WEHLKND1) during the summer over the 5-year period of 2002 to 2006.

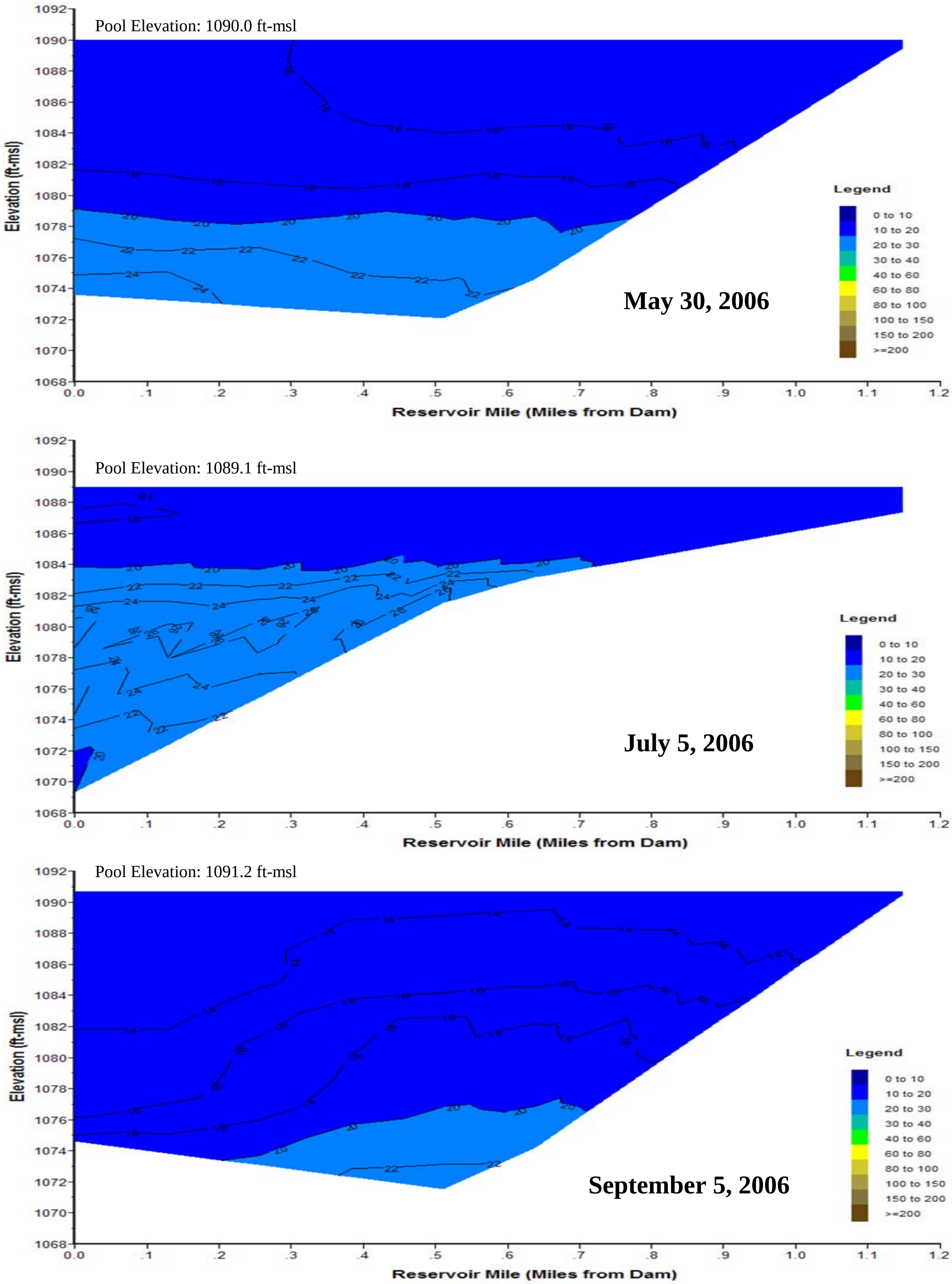

Plate 37. Longitudinal turbidity (NTU) contour plots of Wehrspann Reservoir based on depth-profile turbidity levels measured at sites WEHLKND1 and WEHLKML1 in May, July, and September 2006.

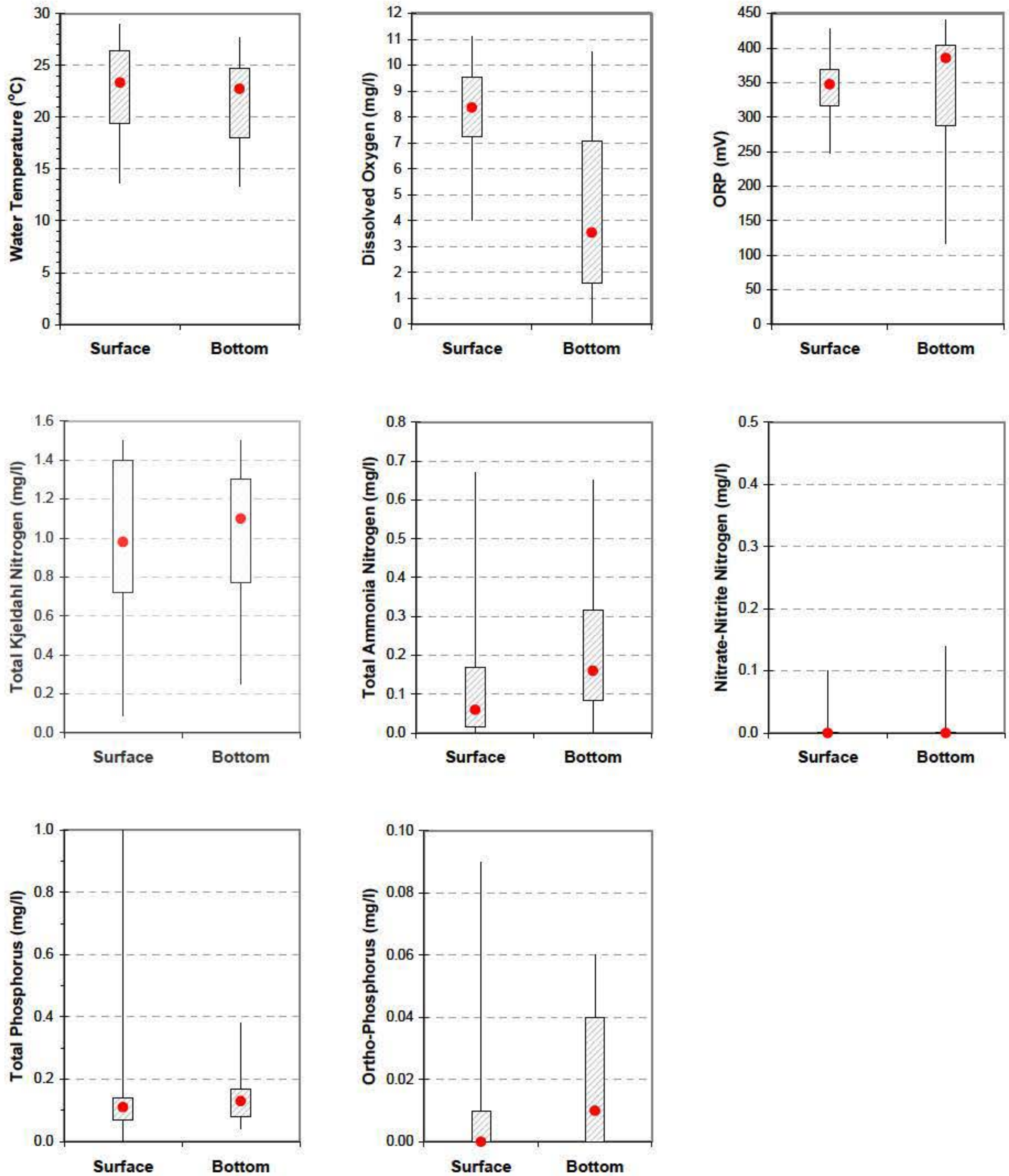

Plate 38. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Wehrspann Reservoir at site WEHLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

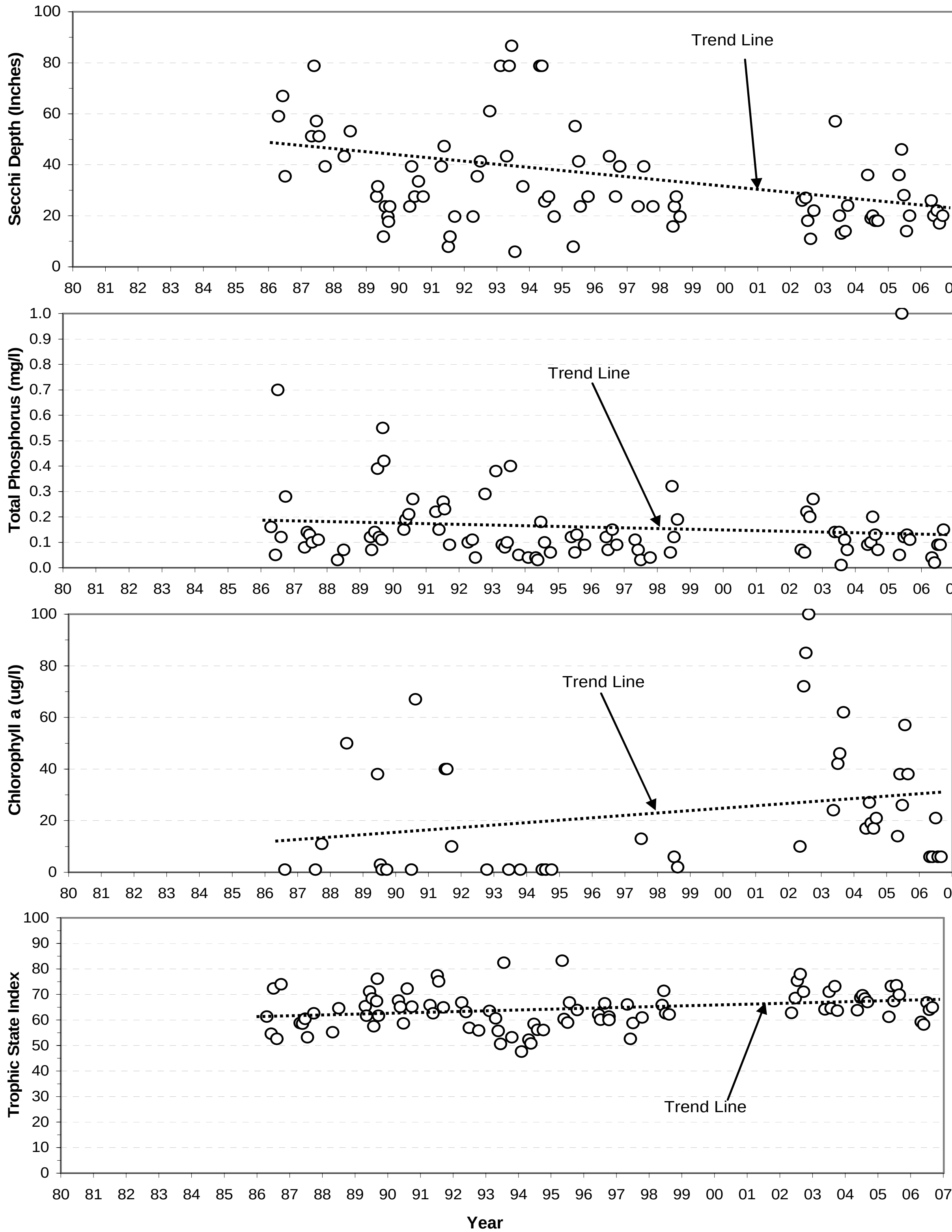

Plate 39. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Wehrspann Reservoir at the near-dam, ambient site (i.e., site WEHLKND1) over the 27-year period of 1980 to 2006.

Plate 40. Summary of runoff water quality conditions monitored in the main tributary inflow to Wehrspann Reservoir, upstream of the constructed sediment basin/wetland, at monitoring site WEHNFUSB1 during the period 2002 through 2006.

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Turbidity (NTUs)	0.1	7	2,239	1,930	89	7,218	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	195	210	62	327	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	----	0.35	n.d.	2.00	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	14	4.3	4.4	0.8	11.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	14	1.86	1.55	0.21	6.00		-----	-----
Phosphorus, Total (mg/l)	0.01	14	1.87	1.50	0.03	5.90	-----	-----	-----
Suspended Solids, Total (mg/l)	4	14	1,565	951	5	5,630	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	14	-----	0.07	n.d.	1.40	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	14	11.35	0.78	n.d.	120.00	330(2), 12(3)	3	21%
Metolachlor, Total (ug/l)***	0.05	14	2.70	0.59	n.d.	27.00	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 41. Summary of runoff water quality conditions monitored in the main tributary inflow to Wehrspann Reservoir, immediately below the constructed sediment basin/wetland, at monitoring site WEHNFDSB1 during the period 2002 through 2006.

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Turbidity (NTUs)	0.1	7	28	22	7	73	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	139	122	86	246	-----	-----	-----
Ammonia N, Total (mg/l)	0.01	9	-----	0.28	n.d.	1.10	(1)	(1)	(1)
Kjeldahl N, Total (mg/l)	0.1	14	1.2	1.3	0.3	2.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	14	0.78	0.26	n.d.	4.50		-----	-----
Phosphorus, Total (mg/l)	0.01	14	0.29	0.18	0.04	1.30	-----	-----	-----
Suspended Solids, Total (mg/l)	4	14	66	16	6	630	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	14	-----	0.09	n.d.	0.96	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	14	2.09	1.38	n.d.	10.00	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	13	0.78	0.45	n.d.	2.80	390(2), 100(3)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Total ammonia criteria pH and temperature dependent. Criteria not able to be calculated.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
*** Immunoassay analysis.

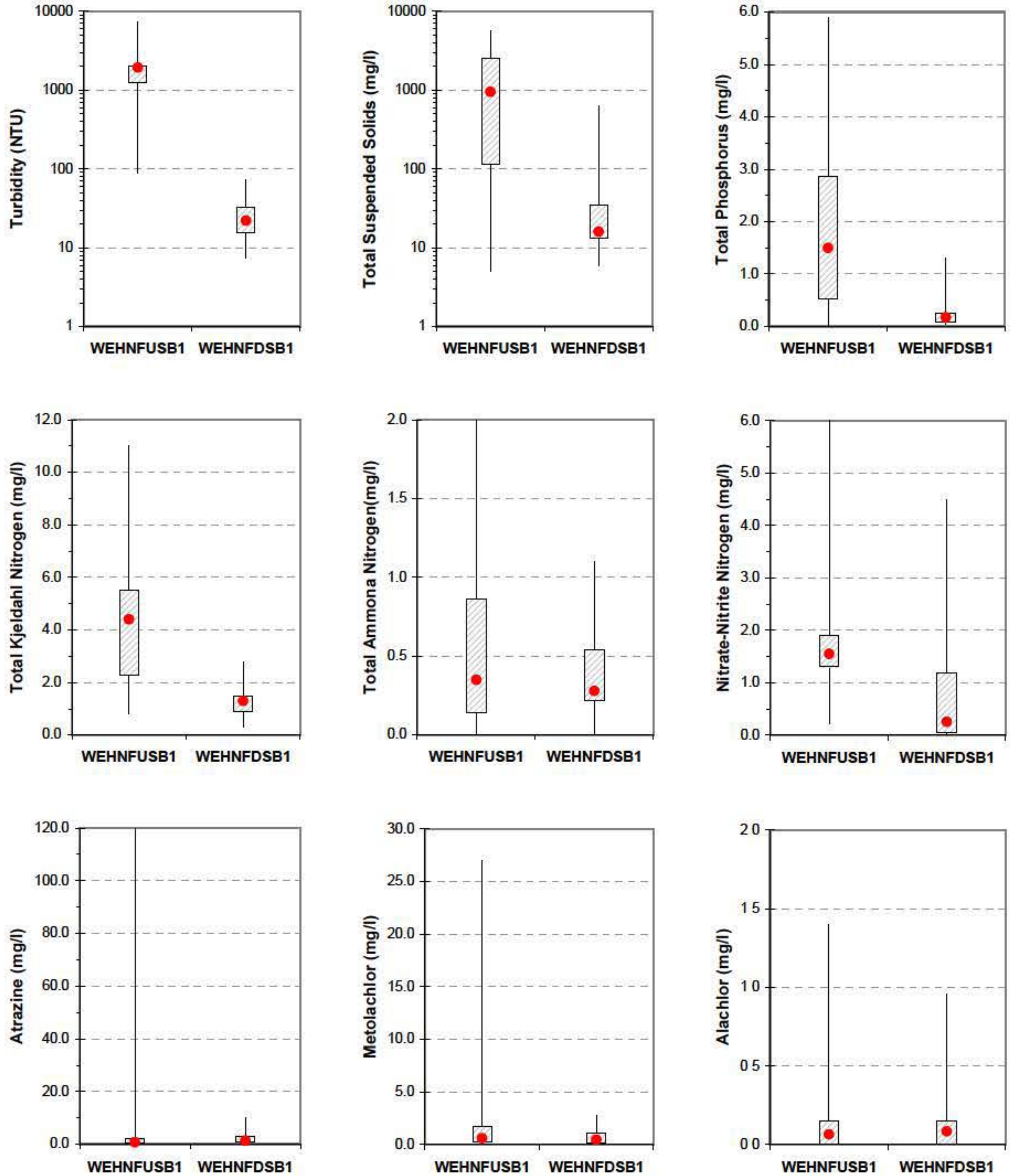

Plate 42. Box plots comparing paired runoff samples collected upstream (i.e., site WEHNFUSB1) and downstream (i.e., WEHNFDSB1) of the constructed sediment basin/wetland at Wehrspann Reservoir during the period 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between upstream and downstream measurements.)

Plate 43. Summary of water quality conditions monitored in Bluestem Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site BLULKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1305.7	1306.2	1301.6	1308.0	-----	-----	-----
Water Temperature (C)	0.1	188	22.1	22.5	15.1	28.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	188	6.9	7.1	0.4	9.2	≥ 5.0	11	6%
Dissolved Oxygen (% Sat.)	0.1	182	81.1	82.8	5.0	122.3	-----	-----	-----
Specific Conductance (umho/cm)	1	181	282	294	187	339	-----	-----	-----
pH (S.U.)	0.1	182	8.0	8.0	7.1	8.9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	120	138.9	109.6	27.4	502.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	130	394	392	299	488	-----	-----	-----
Secchi Depth (in.)	1	25	8	6	2	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	107	111	46	149	-----	-----	-----
Ammonia, Total (mg/l)	0.01	36	-----	0.19	n.d.	1.00	8.40 (1,2), 1.45 (1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	43	29	34	14	59	16(5)	23	53%
Chlorophyll *a* (ug/l) – Lab Determined	1	21	19	3	n.d.	101	16(5)	7	33%
Hardness, Total (mg/l)	0.4	14	139	144	99	159	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	0.9	0.9	n.d.	3.8	-----	-----	-----
Nitrogen, Total (mg/)	0.1	48	1.6	1.6	0.3	4.6	1.54(5)	25	52%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	0.65	0.63	n.d.	1.70	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.24	0.21	0.02	0.99	0.143(5)	45	90%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	0.09	0.09	n.d.	0.18	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	40	28	8	140	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	6	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	8.4(2), 0.3(3)	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	798(2), 104(3)	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	2	19.0(2), 12.2(3)	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	96(2), 3.7(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	637(2), 71(3)	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	6 5(2)	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400(2), 6.3(3)	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	160(2,3)	0	0%
Microcystins, Total (ug/l)	0.2	9	-----	n.d.	n.d.	1.5	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	24	0.34	0.31	0.08	0.98	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	26	1.89	1.39	n.d.	11.60	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)***	0.05	25	1.30	1.10	0.26	2.90	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)****	0.05	5	-----				*****	0	0%
Acetochlor			-----	-----	n.d.	0.10			
Atrazine			-----	1.39	n.d.	2.30			
Metolachlor			-----	n.d.	n.d.	0.15			
Prometon			-----	0.20	n.d.	0.87			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.0 and 22.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 144 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 44. Summary of water quality conditions monitored in Bluestem Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site BLULKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	24	1305.6	1306.1	1301.6	1308.0	-----	-----	-----
Water Temperature (C)	0.1	150	22.1	22.4	14 9	28.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	150	7.1	7.2	3 2	8.9	≥ 5.0	3	2%
Dissolved Oxygen (% Sat.)	0.1	145	83.5	82.7	40 5	118.7	-----	-----	-----
Specific Conductance (umho/cm)	1	145	281	295	188	336	-----	-----	-----
pH (S.U.)	0.1	145	8.1	8.0	7 3	8.9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	96	145.3	113.9	26 9	615.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	107	393	400	314	475	-----	-----	-----
Secchi Depth (in.)	1	24	7	6	2	17	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	38	31	35	13	63	16(1)	28	74%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Nutrient criteria.

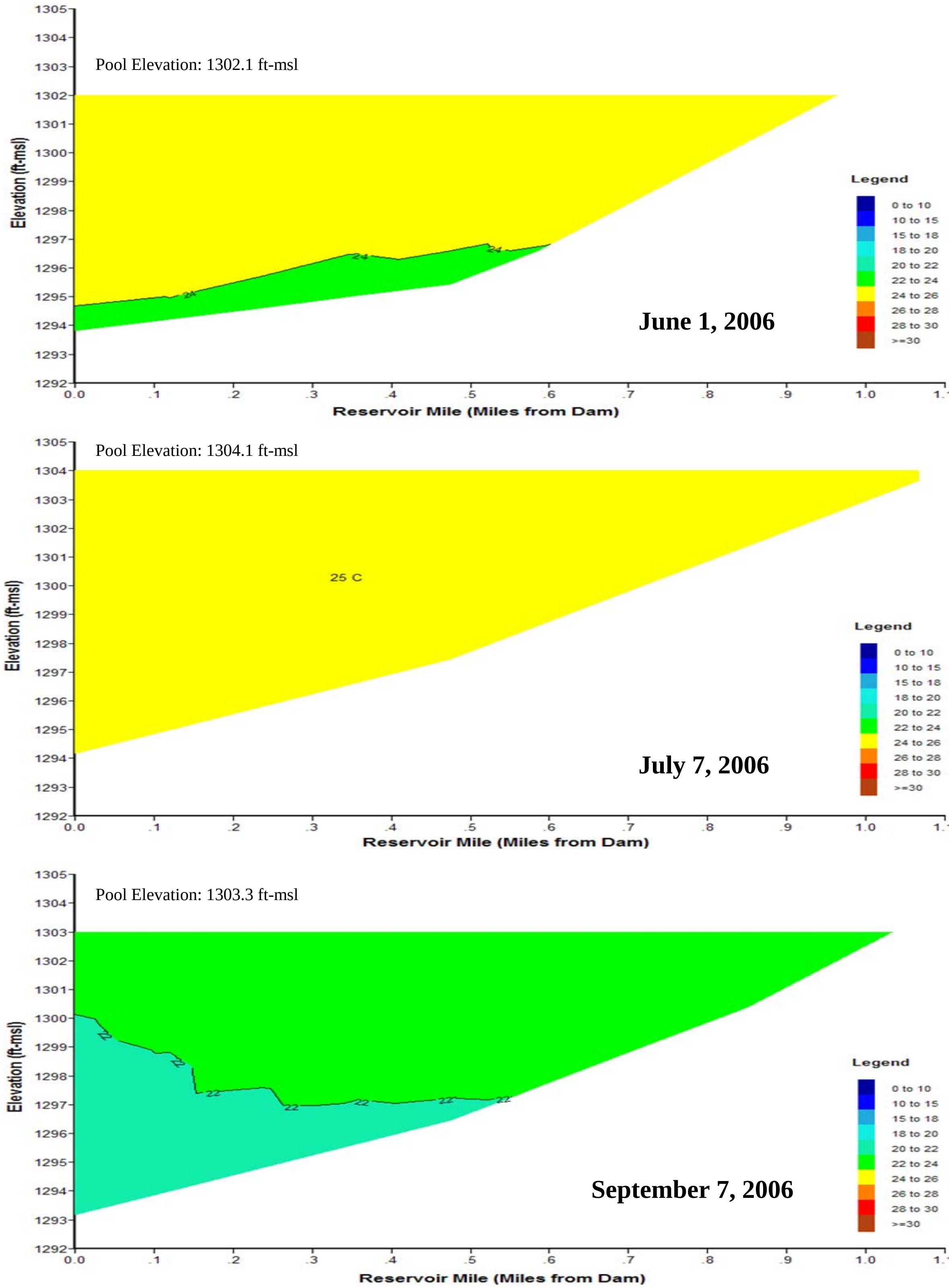

Plate 45. Longitudinal water temperature (°C) contour plots of Bluestem Reservoir based on depth-profile water temperatures measured at sites BLULKND1 and BLULKML1 in June, July, and September 2006.

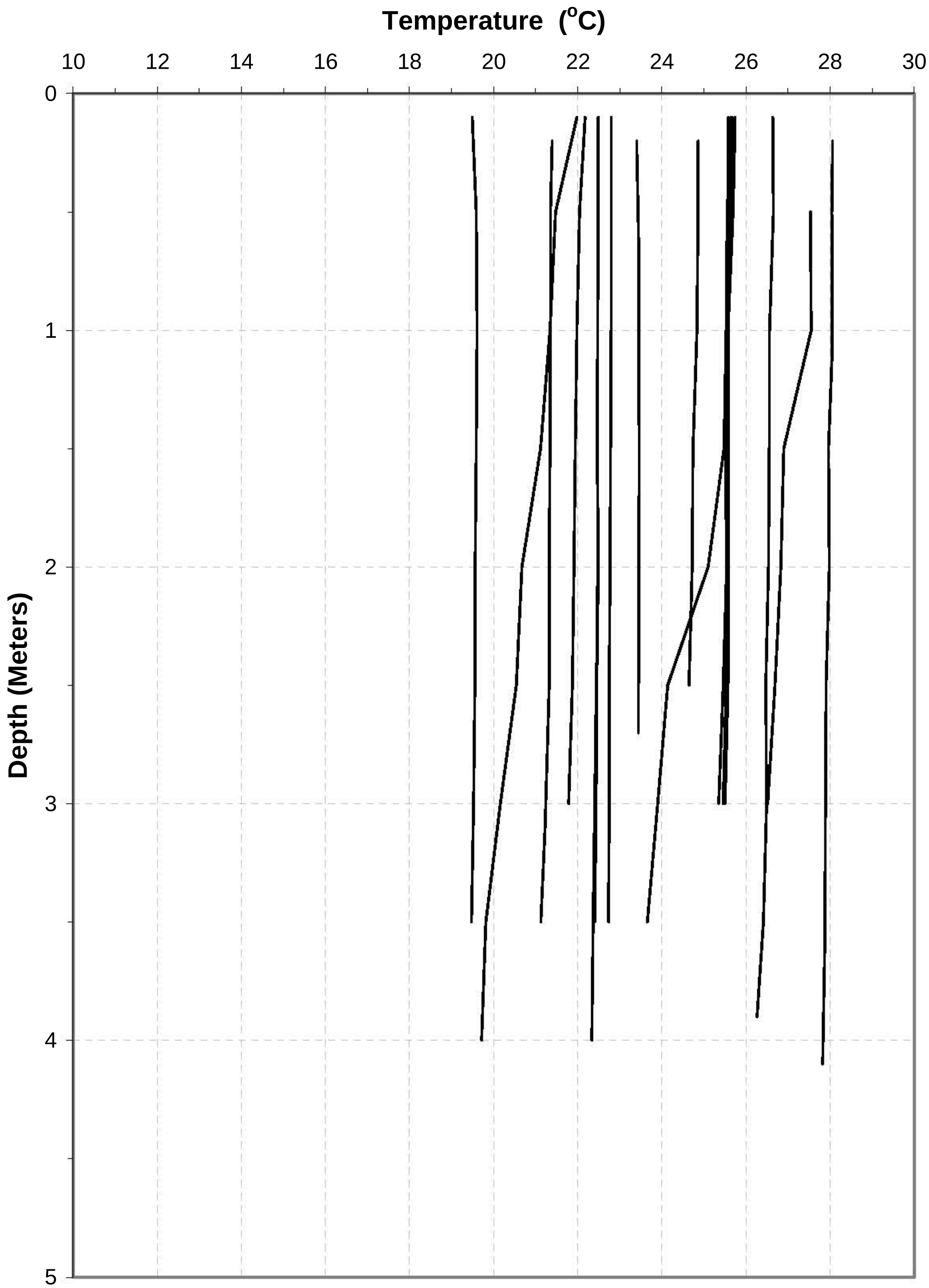

Plate 46. Temperature depth profiles for Bluestem Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BLULKND1) during the summer over the 5-year period of 2002 to 2006.

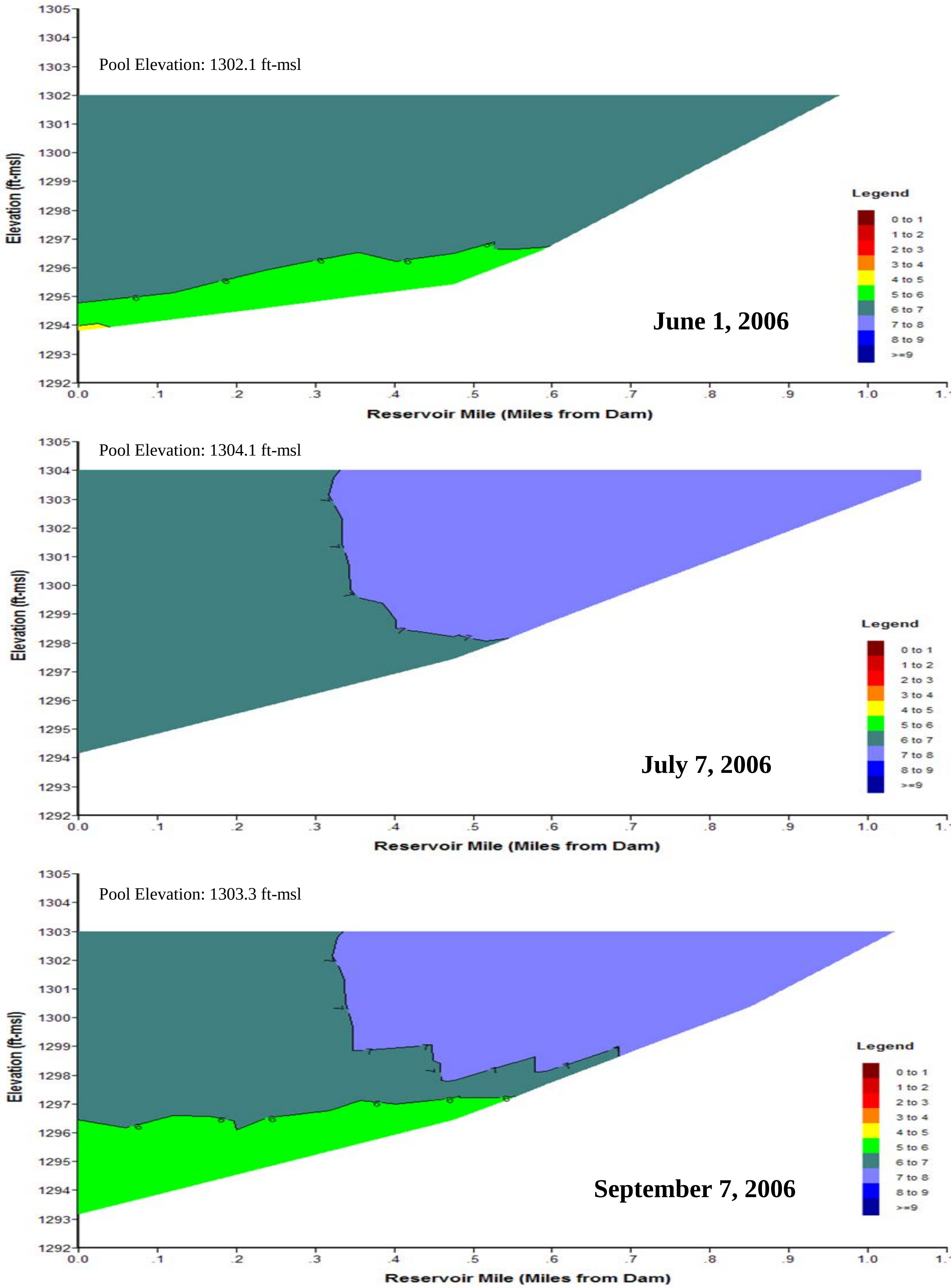

Plate 47. Longitudinal dissolved oxygen (mg/l) contour plots of Bluestem Reservoir based on depth-profile dissolved oxygen concentrations measured at sites BLULKND1 and BLULKML1 in June, July, and September 2006.

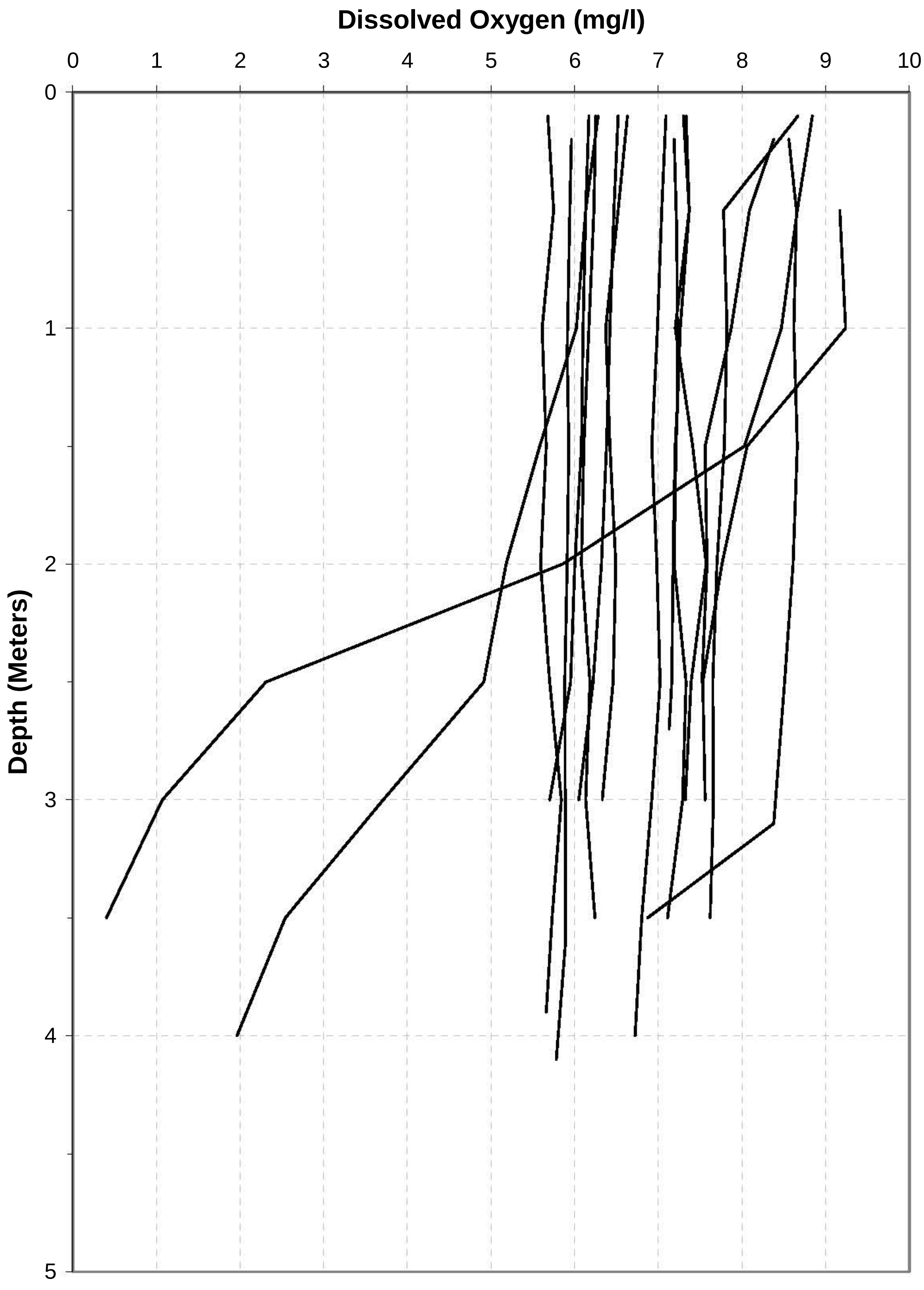

Plate 48. Dissolved oxygen depth profiles for Bluestem Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BLULKND1) during the summer over the 5-year period of 2002 to 2006.

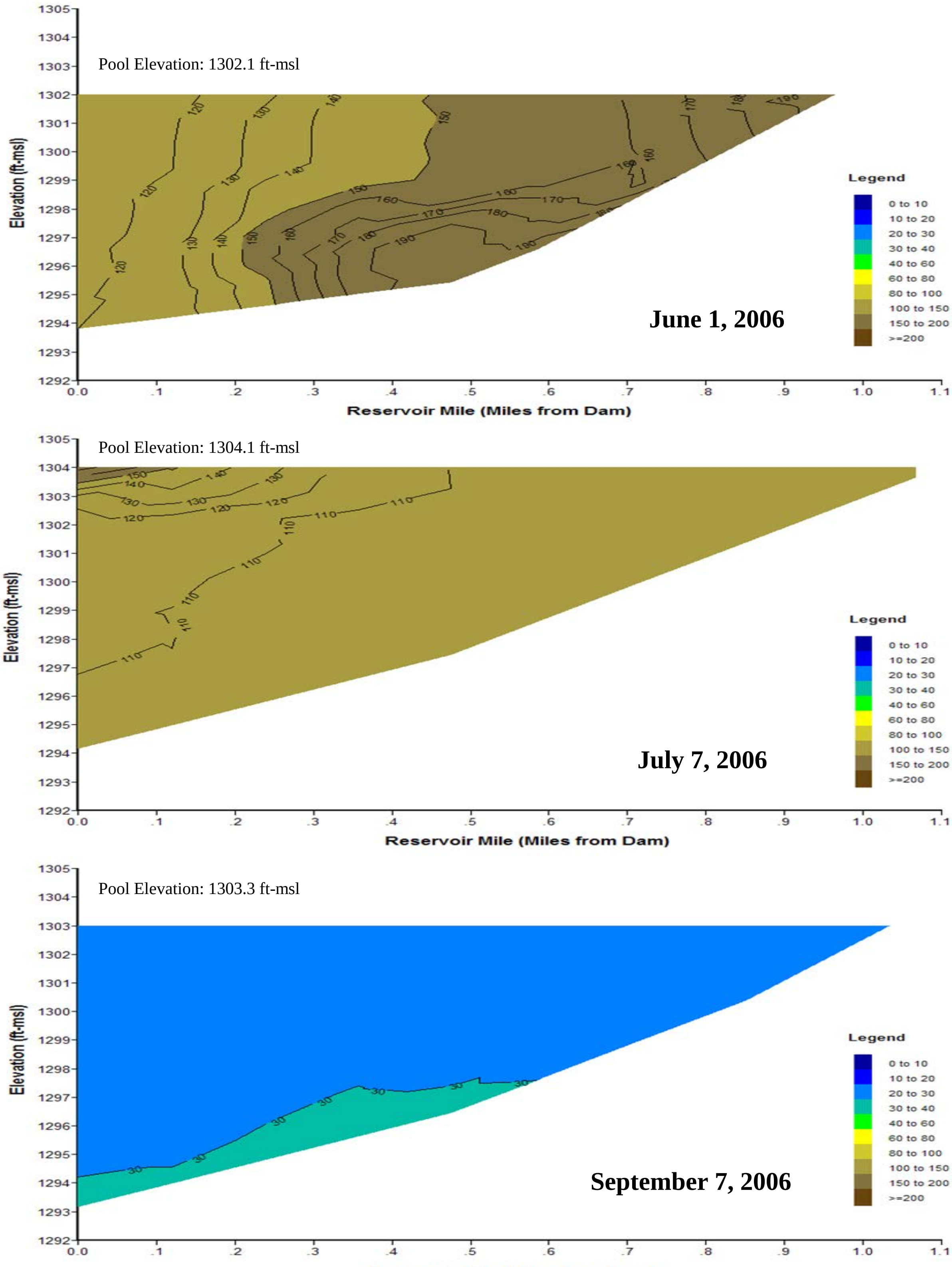

Plate 49. Longitudinal turbidity (NTU) contour plots of Bluestem Reservoir based on depth-profile turbidity levels measured at sites BLULKND1 and BLULKML1 in June, July, and September 2006.

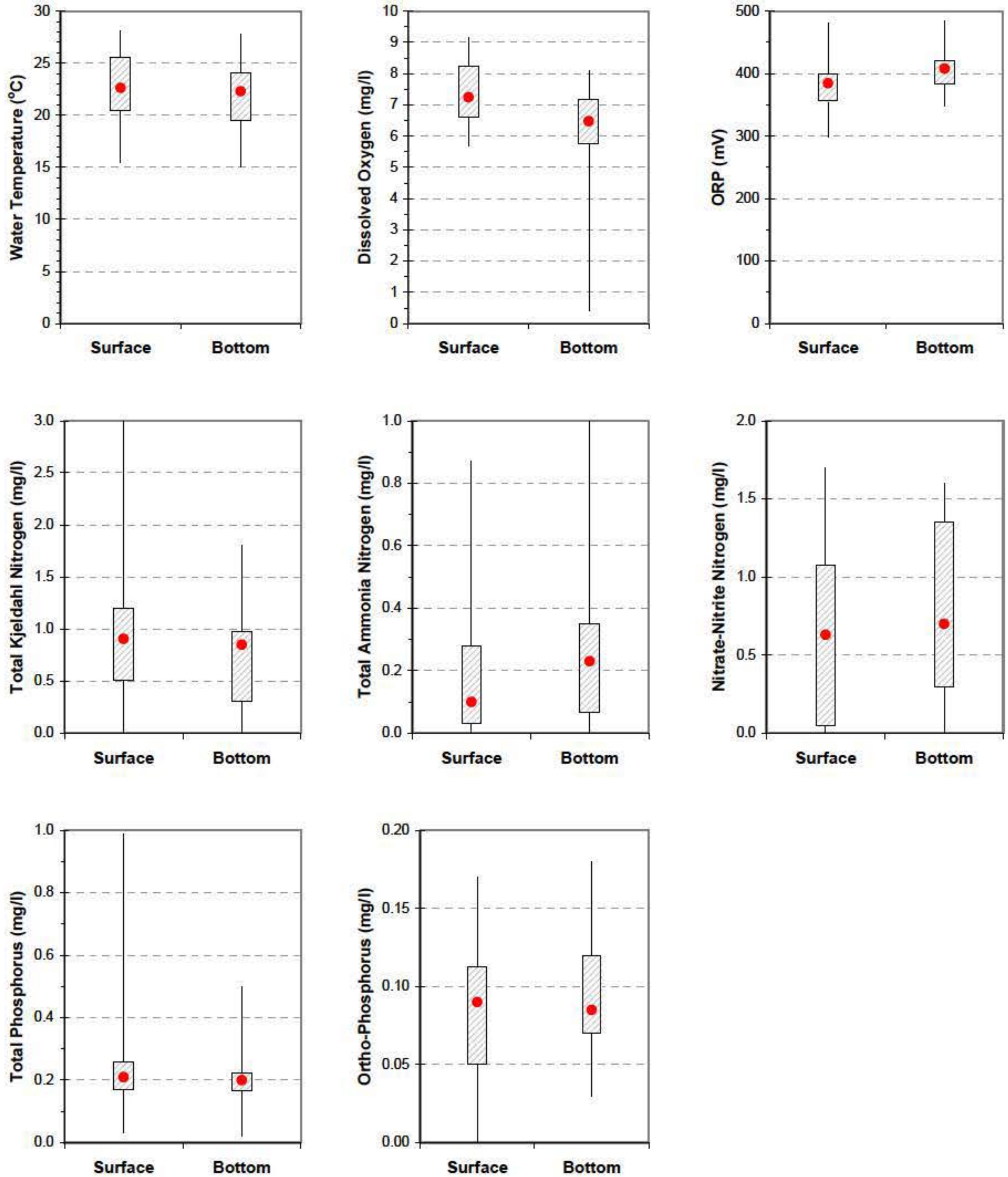

Plate 50. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Bluestem Reservoir at site BLULKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

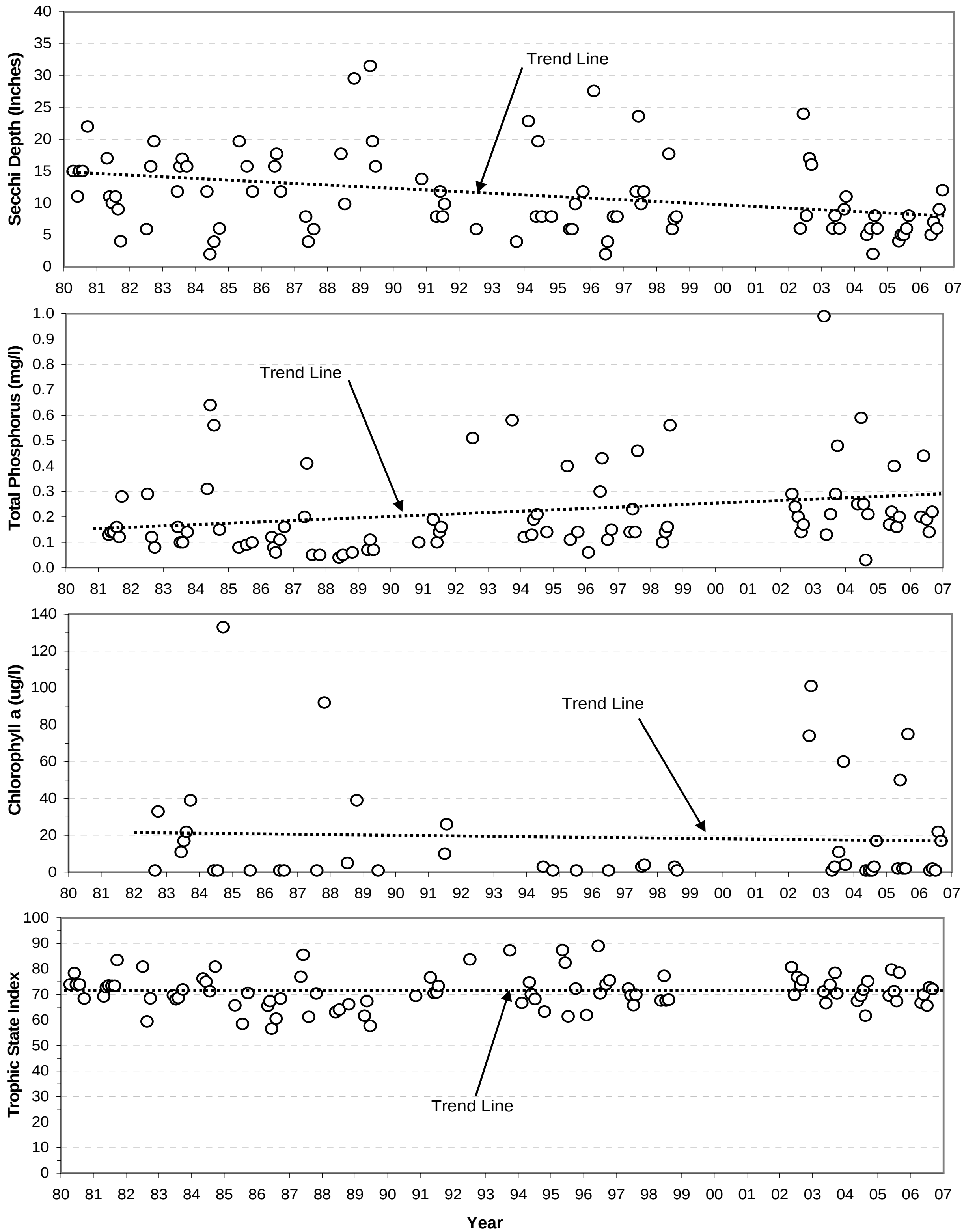

Plate 51. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Bluestem Reservoir at the near-dam, ambient site (i.e., site BLULKND1) over the 27-year period of 1980 to 2006.

Plate 52. Summary of runoff water quality conditions monitored in the main north tributary inflow to Bluestem Reservoir at monitoring site BLUNFNRT1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	850	850	91	1608	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	8	6.1	6.8	0.6	11.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	8	7.24	3.83	1.16	26.75		-----	-----
Phosphorus, Total (mg/l)	0.01	8	2.03	2.24	0.42	3.07	-----	-----	-----
Suspended Solids, Total (mg/l)	4	8	856	797	22	1,890	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	8	0.47	0.25	0.05	1.97	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	8	30.68	19.80	0.05	105.04	330(1), 12(2)	0, 6	0%, 75%
Metolachlor, Total (ug/l)***	0.05	8	2.76	1.89	0.10	10.10	390(1), 100(2)	0	0%
E. Coli (cfu/100ml)	1	2	22,432	22,432	19,863	25,000	-----	-----	-----

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 53. Summary of runoff water quality conditions monitored in the main west tributary inflow to Bluestem Reservoir at monitoring site BLUNFWST1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	988	988	287	1,689	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	8	5.7	7.0	1.6	7.7	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	8	1.70	1.80	0.52	2.56		-----	-----
Phosphorus, Total (mg/l)	0.01	8	3.30	2.83	0.31	9.84	-----	-----	-----
Suspended Solids, Total (mg/l)	4	8	1,558	1,465	115	3,000	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	8	1.55	0.79	0.10	4.21	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	8	17.96	20.24	0.09	45.87	330(1), 12(2)	0, 5	0%, 63%
Metolachlor, Total (ug/l)***	0.05	7	5.82	0.55	0.05	32.89	390(1), 100(2)	0	0%
E. Coli (cfu/100ml)	1	2	14,535	14,535	9,208	19,863	-----	-----	-----

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 54. Summary of water quality conditions monitored in Branched Oak Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site BOKLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1279.4	1279.4	1278.5	1280.9	-----	-----	-----
Water Temperature (C)	0.1	326	21.7	22.1	14.1	29.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	326	7.1	6.7	0.3	13.0	≥ 5.0	19	6%
Dissolved Oxygen (% Sat.)	0.1	312	82.1	81.5	3.5	173.2	-----	-----	-----
Specific Conductance (umho/cm)	1	312	399	397	354	468	-----	-----	-----
pH (S.U.)	0.1	312	8.3	8.3	7.4	9.1	≥6.5 & ≤9.0	2	1%
Turbidity (NTUs)	0.1	184	21.3	22.5	5.3	59.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	205	384	367	86	515	-----	-----	-----
Secchi Depth (in.)	1	25	21	19	14	39	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	168	170	124	200	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	-----	0.14	n.d.	1.30	4.71 [1,2], 0.93 [1,3]	0, 1	0%, 3%
Chlorophyll *a* (ug/l) – Field Probe	1	71	38	33	12	86	16[5]	70	99%
Chlorophyll *a* (ug/l) – Lab Determined	1	22	23	18	4	108	16[5]	13	59%
Hardness, Total (mg/l)	0.4	19	162	167	97	178	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	0.9	1.1	n.d.	1.5	-----	-----	-----
Nitrogen, Total (mg/)	0.1	48	0.92	1.00	n.d.	1.50	1.54[5]	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.14	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.11	0.09	n.d.	0.76	0.143[5]	6	12%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	16	14	n.d.	32	-----	-----	-----
Antimony, Dissolved (ug/l)	6	4	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	5	-----	3	n.d.	4	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	9.7[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	901[2], 117[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	2	21.8[2], 13.9[3]	0	0%
Lead, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	112[2], 4.4[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	5	-----	n.d.	n.d.	8	723[2], 80[3]	0	0%
Selenium, Total (ug/l)	2	5	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	8 3[2]	0	0%
Thallium (ug/l)	6	4	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	3	n.d.	23	181[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	22	0.18	0.18	n.d.	0.27	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	22	2.31	2.35	0.94	3.16	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	21	0.12	0.11	n.d.	0.34	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	5	-----				*****	0	0%
Atrazine			1.25	1.00	n.d.	2.80			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 22.1 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 167 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 55. Summary of water quality conditions monitored in Branched Oak Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site BOKLKMLN1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1279.4	1279.4	1278 5	1280.9	-----	-----	-----
Water Temperature (C)	0.1	174	21.9	22.5	13.7	29.4	32	0	0%
Dissolved Oxygen (mg/l)	0.1	174	7.7	7.8	0.4	13.7	≥ 5.0	4	2%
Dissolved Oxygen (% Sat.)	0.1	164	90.9	88.0	5 3	185.4	-----	-----	-----
Specific Conductance (umho/cm)	1	164	398	396	352	451	-----	-----	-----
pH (S.U.)	0.1	164	8.4	8.4	7 5	9.1	≥6.5 & ≤9.0	4	2%
Turbidity (NTUs)	0.1	101	27.5	28.0	9.8	53.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	113	382	364	290	517	-----	-----	-----
Secchi Depth (in.)	1	23	18	18	9	32	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	42	53	45	5	150	16[1]	37	88%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Nutrient criteria.

Plate 56. Summary of water quality conditions monitored in Branched Oak Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site BOKLKMLS1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1279.4	1279.4	1278 5	1280.9	-----	-----	-----
Water Temperature (C)	0.1	179	21.7	22.2	14.0	27.7	32	0	0%
Dissolved Oxygen (mg/l)	0.1	179	7.4	7.3	3 9	11.2	≥ 5.0	6	3%
Dissolved Oxygen (% Sat.)	0.1	173	87.0	86.3	49 3	132.5	-----	-----	-----
Specific Conductance (umho/cm)	1	173	398	396	354	453	-----	-----	-----
pH (S.U.)	0.1	173	8.3	8.4	7 9	8.8	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	105	26.4	26.7	9 9	53.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	122	384	364	278	518	-----	-----	-----
Secchi Depth (in.)	1	23	18	17	12	29	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	45	42	26	3.6	114	16[1]	35	78%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Nutrient criteria.

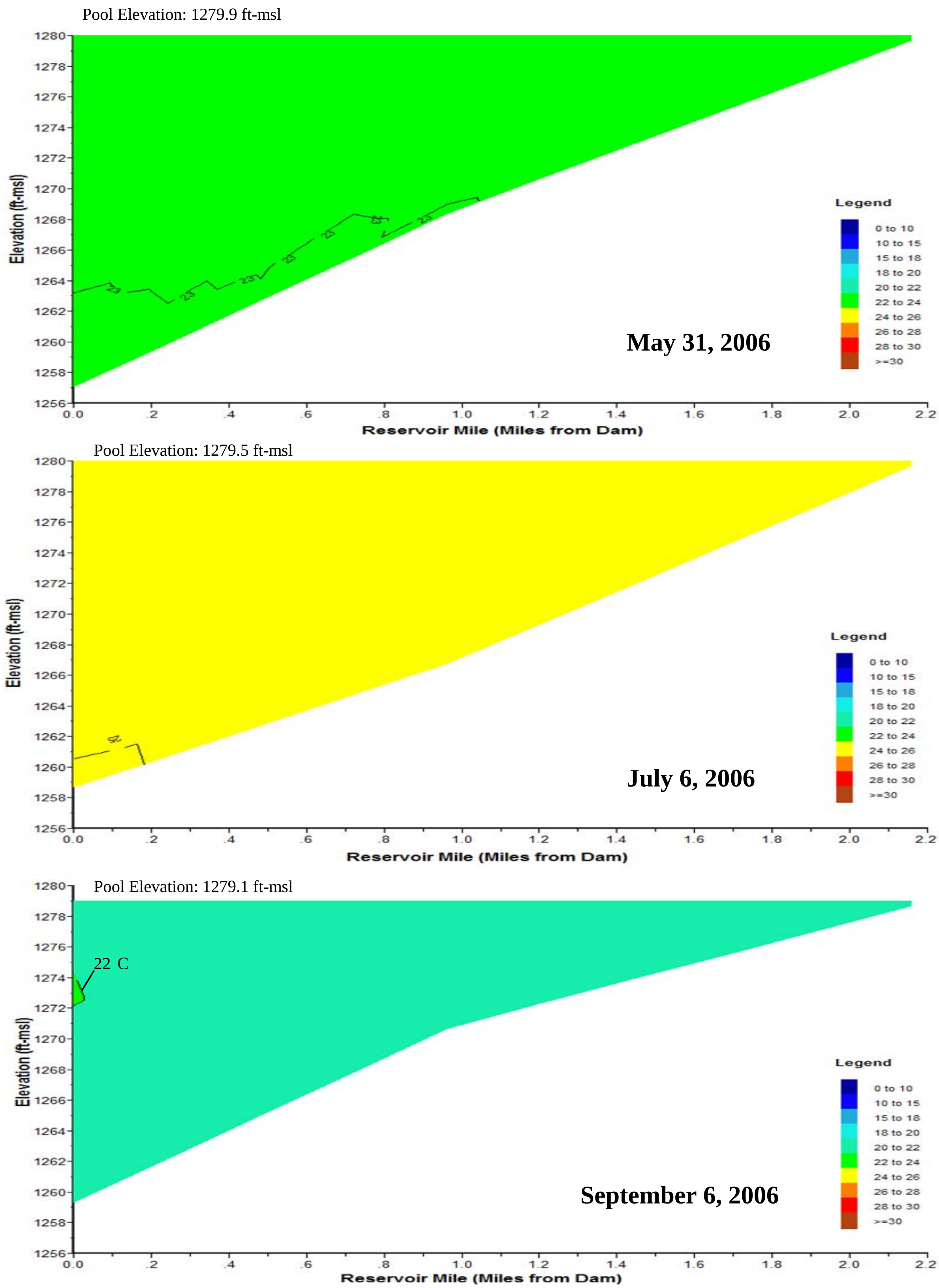

Plate 57. Longitudinal water temperature (°C) contour plots of Branched Oak Reservoir through the north arm based on depth-profile water temperatures measured at sites BOKLKND1 and BOKLKMLN1 in May, July, and September 2006.

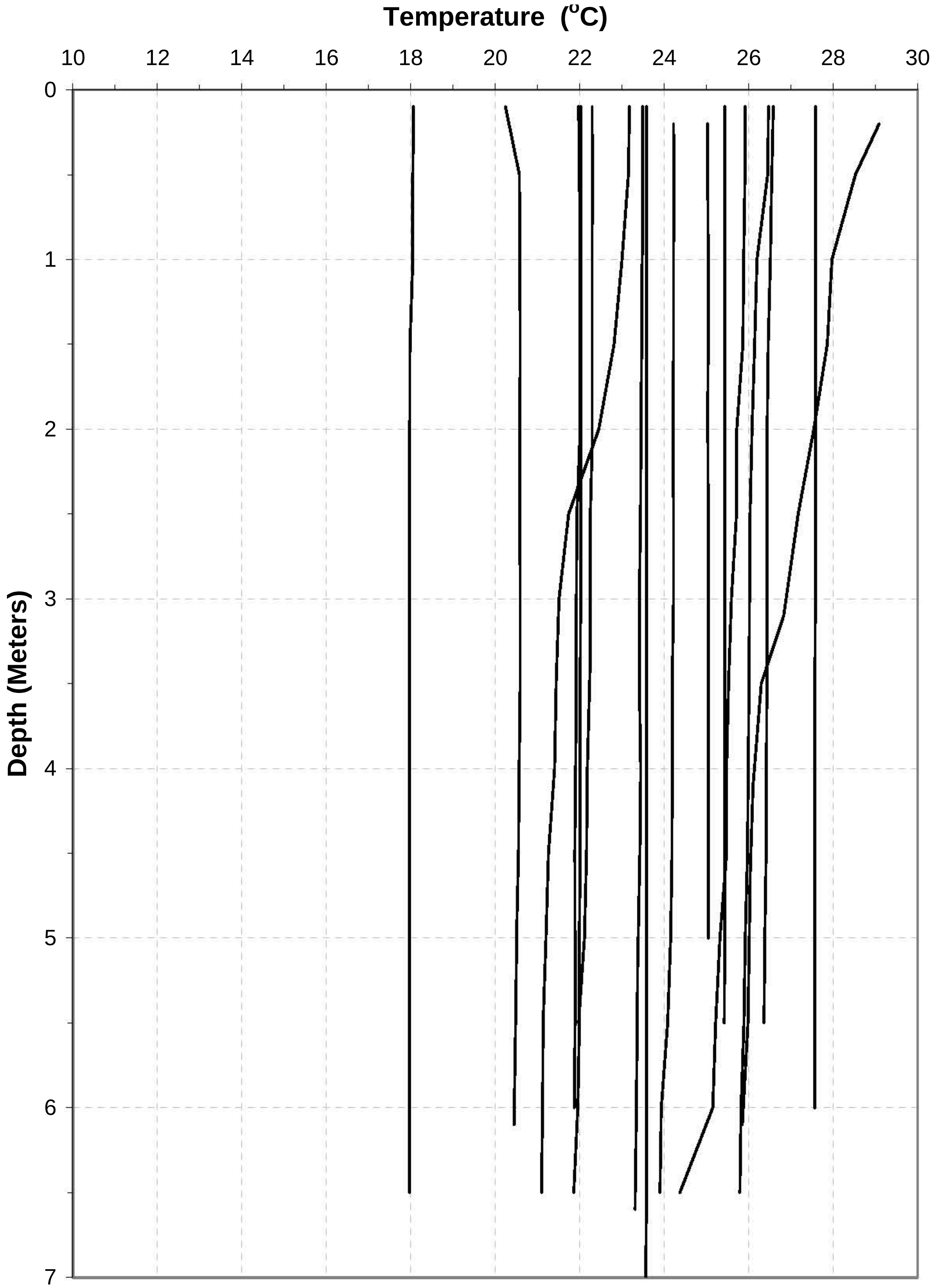

Plate 58. Temperature depth profiles for Branched Oak Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BOKLKND1) during the summer over the 5-year period of 2002 to 2006

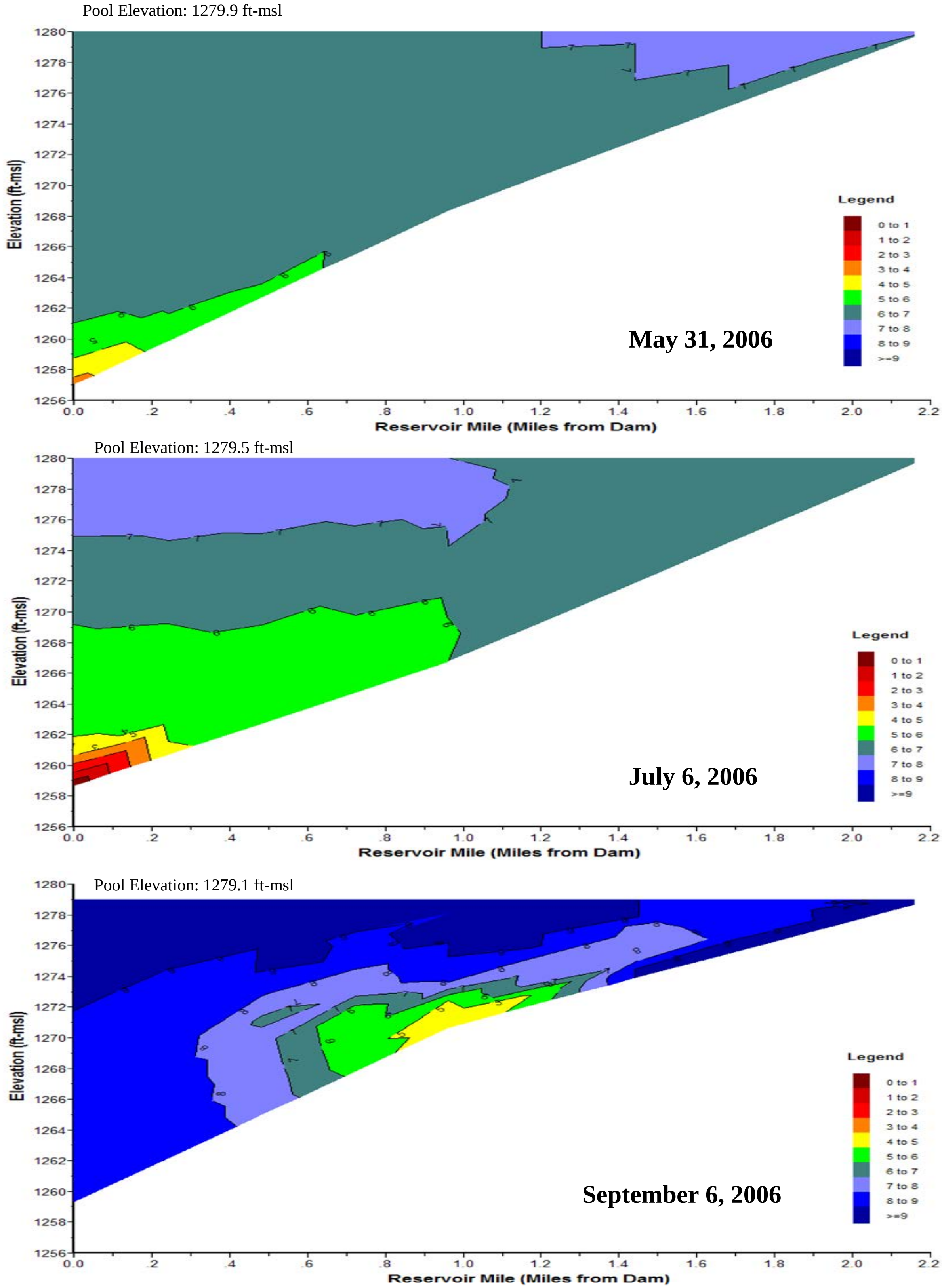

Plate 59. Longitudinal dissolved oxygen (mg/l) contour plots of Branched Oak Reservoir through the north arm based on depth-profile dissolved oxygen concentrations measured at sites BOKLKND1 and BOKLKMLN1 in May, July, and September 2006.

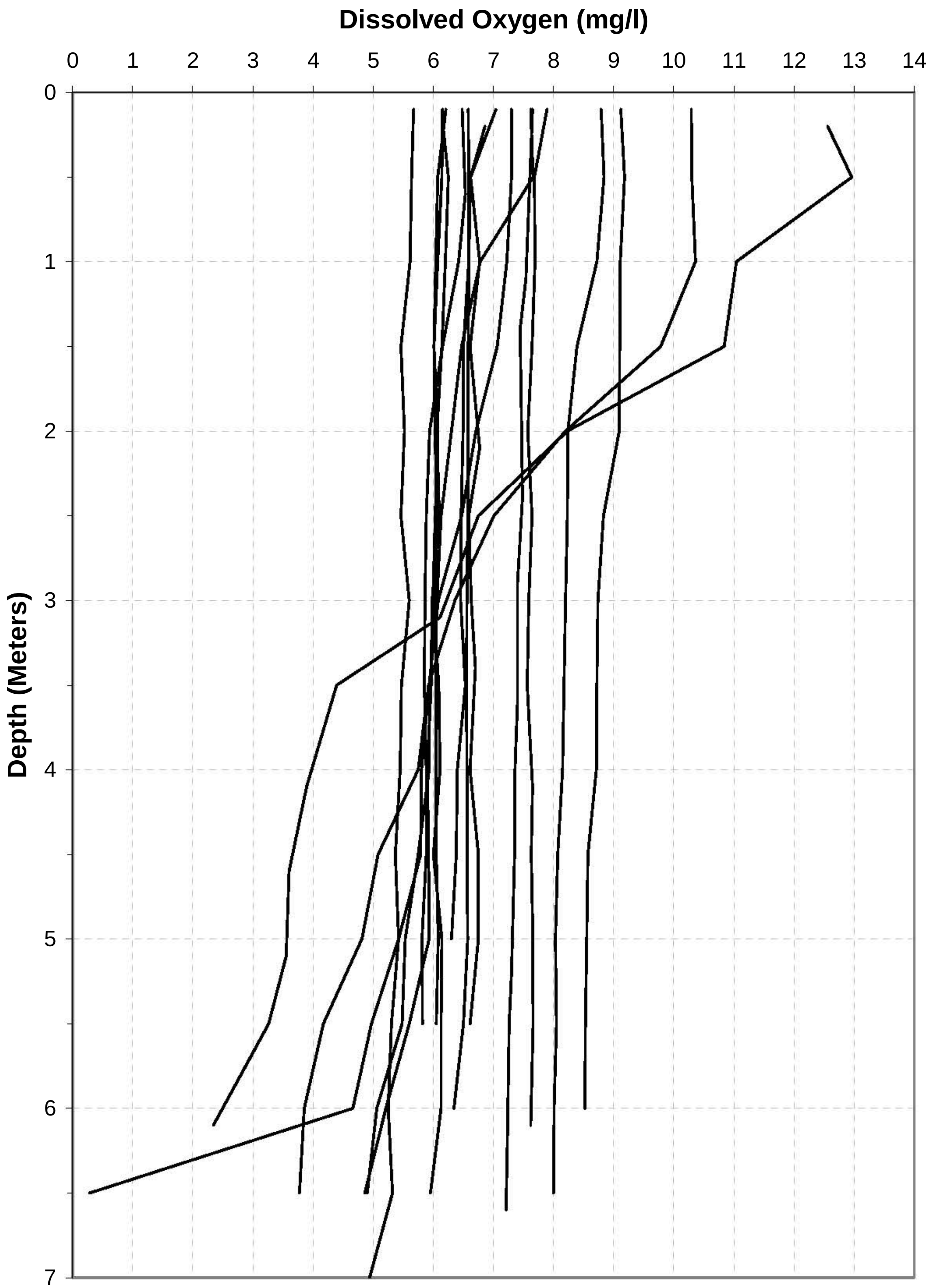

Plate 60. Dissolved oxygen depth profiles for Branched Oak Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BOKLKND1) during the summer over the 5-year period of 2002 to 2006

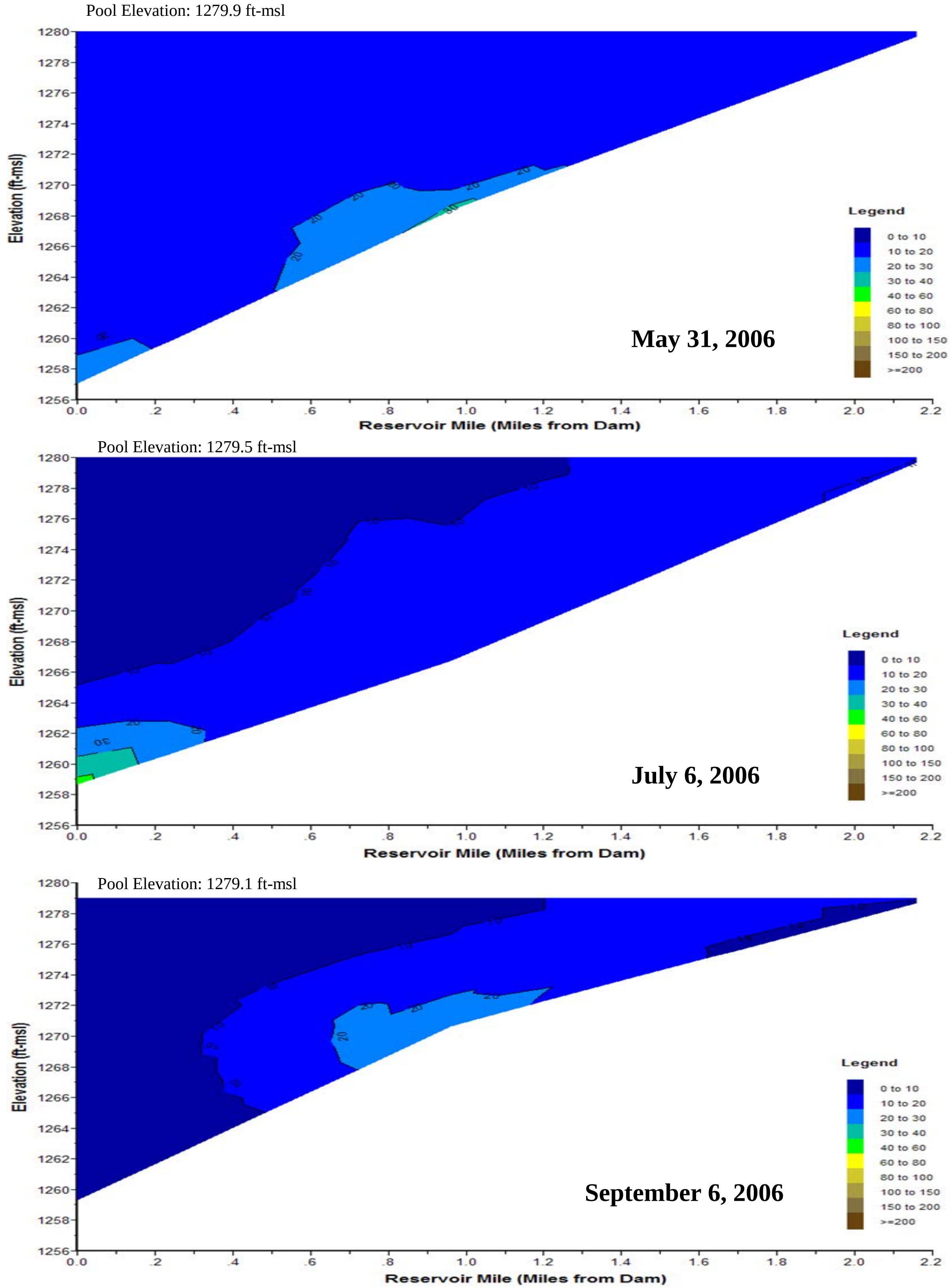

Plate 61. Longitudinal turbidity (NTU) contour plots of Branched Oak Reservoir through the north arm based on depth-profile turbidity levels measured at sites BOKLKND1 and BOKLKMLN1 in May, July, and September 2006.

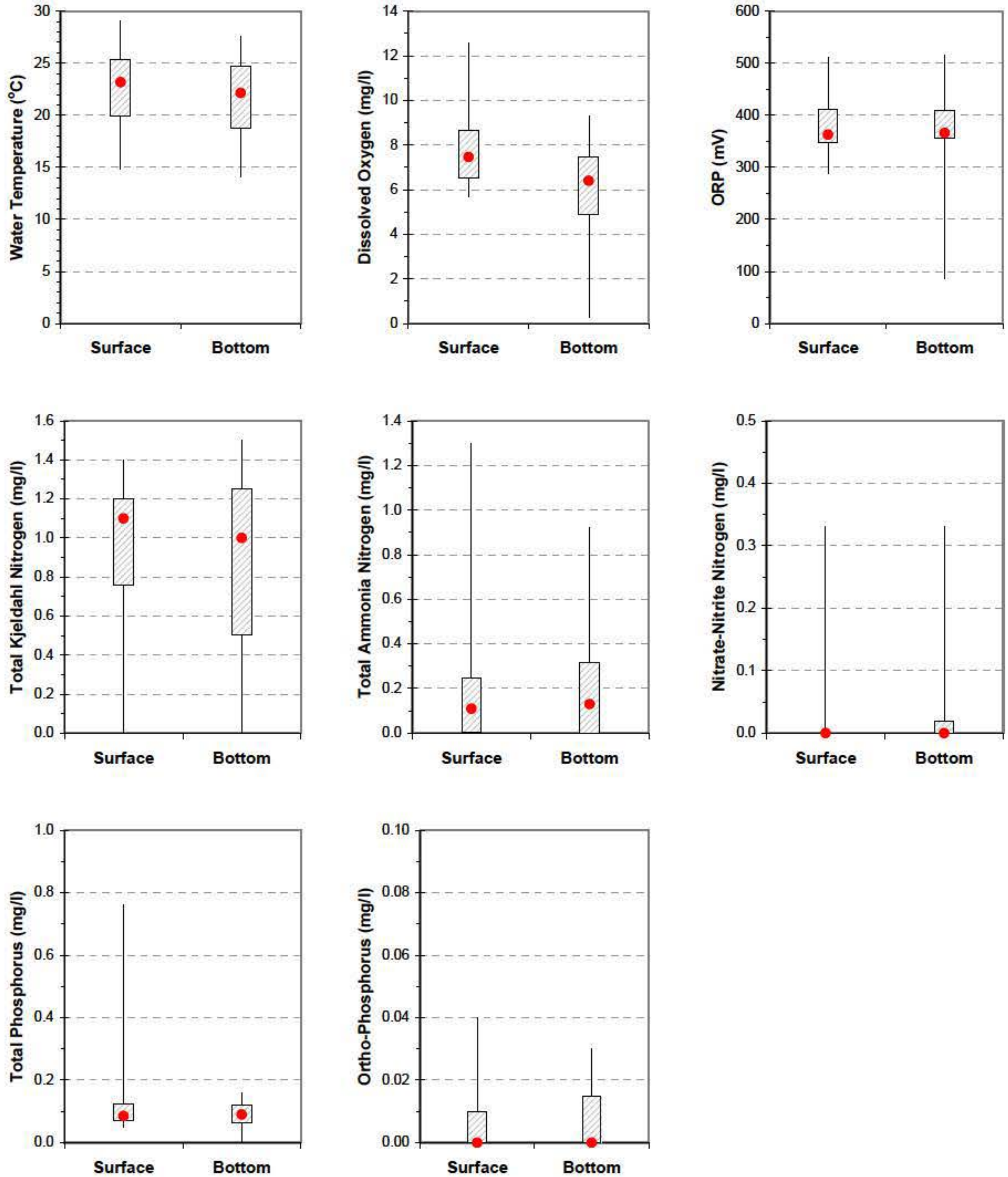

Plate 62. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Branched Oak Reservoir at site BOKLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

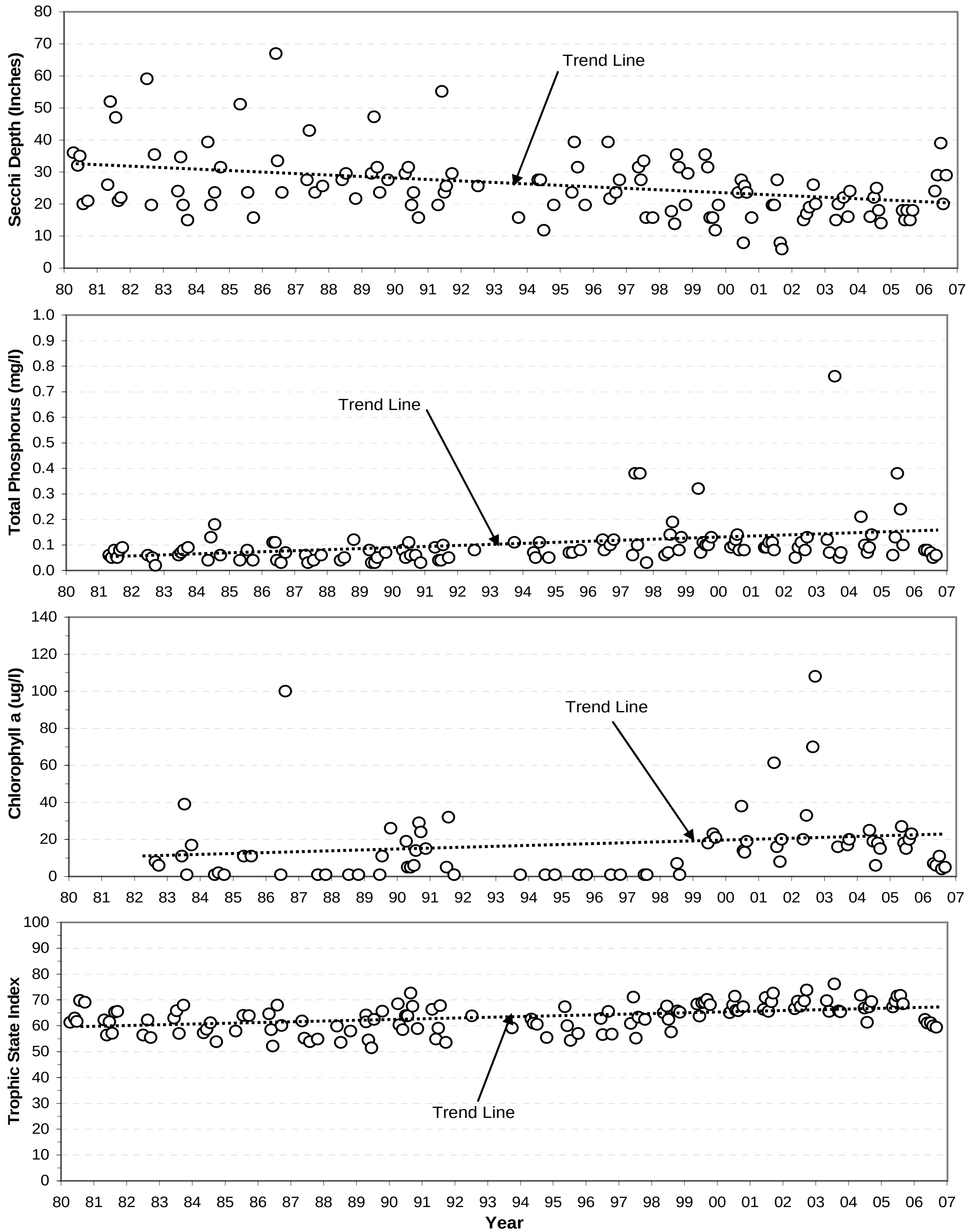

Plate 63. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Branched Oak Reservoir at the near-dam, ambient site (i.e., site BOKLKND1) over the 27-year period of 1980 to 2006.

Plate 64. Summary of runoff water quality conditions monitored in the main north tributary inflow to Branched Oak Reservoir at monitoring site BOKNFNRT1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	103.3	103.3	81.6	125.0	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	9	3.6	2.3	1.0	8.2	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	1.9	1.4	0.1	7.3		-----	-----
Phosphorus, Total (mg/l)	0.01	9	0.95	0.47	0.27	2.27	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	546	242	38	2,020	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	9	0.28	0.16	0.09	0.97	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	9	7.51	3.93	0.06	22.11	330(1), 12(2)	0, 3	0%, 33%
Metolachlor, Total (ug/l)***	0.05	9	3.67	0.34	0.16	28.49	390(1), 100(2)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 65. Summary of runoff water quality conditions monitored in the main west tributary inflow to Branched Oak Reservoir at monitoring site BOKNFWST1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Turbidity (NTUs)	0.1	2	78.9	78.9	20.7	137.0	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	9	2.9	2.1	1.1	7.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	0.62	0.56	0.16	1.18		-----	-----
Phosphorus, Total (mg/l)	0.01	9	0.89	0.47	0.24	2.62	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	588	172	22	2,940	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	9	1.29	0.65	0.18	3.39	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	9	6.20	4.47	0.10	17.71	330(1), 12(2)	0, 2	0%, 22%
Metolachlor, Total (ug/l)***	0.05	9	0.82	0.58	0.09	1.97	390(1), 100(2)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 66. Summary of water quality conditions monitored in Conestoga Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site CONLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1230.1	1230.5	1225.8	1232.8	-----	-----	-----
Water Temperature (C)	0.1	177	22.6	22.9	15.5	28.9	32	0	0%
Dissolved Oxygen (mg/l)	0.1	177	7.3	7.3	0.54	15.9	≥ 5.0	17	10%
Dissolved Oxygen (% Sat.)	0.1	172	86.9	86.1	6.8	196.6	-----	-----	-----
Specific Conductance (umho/cm)	1	172	410	403	316	520	-----	-----	-----
pH (S.U.)	0.1	172	8.4	8.4	7.6	9.2	≥6.5 & ≤9.0	17	10%
Turbidity (NTUs)	0.1	102	40.9	35.6	6.9	91	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	113	385	381	255	509	-----	-----	-----
Secchi Depth (in.)	1	25	20	16	6	55	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	144	140	110	188	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	0.30	0.16	n.d.	1.30	3.88 [1,2], 0.75 [1,3]	0, 3	0%, 9%
Chlorophyll *a* (ug/l) – Field Probe	1	41	19	17	6	84	16[5]	22	54%
Chlorophyll *a* (ug/l) – Lab Determined	1	24	48	20	3	476	16[5]	16	67%
Hardness, Total (mg/l)	0.4	17	165	168	136	200	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	1.7	1.6	n.d.	5.9	-----	-----	-----
Nitrogen, Total (mg/)	0.1	46	1.8	1.7	n.d.	5.9	1.54[5]	27	59%
Nitrate-Nitrite N, Total (mg/l)	0.02	46	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.18	0.16	0.05	0.60	0.143[5]	30	60%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	-----	0.04	n.d.	0.53	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	22	19	6	49	-----	-----	-----
Antimony, Dissolved (ug/l)	6	4	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	5	-----	7	n.d.	9	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	9.7[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	901[2], 117[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	2	21.8[2], 13.9[3]	0	0%
Lead, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	112[2], 4.4[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	5	-----	n.d.	n.d.	8	723[2], 80[3]	0	0%
Selenium, Total (ug/l)	2	5	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	8 3[2]	0	0%
Thallium (ug/l)	6	4	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	7	181[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	3.3	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	26	0.40	0.36	0.07	0.93	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	26	3.14	3.18	1.30	5.90	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	26	0.24	0.19	n.d.	0.87	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	5					*****	0	0%
Acetochlor			-----	n.d.	n.d.	0.10			
Atrazine			0.84	0.59	n.d.	1.80			
Metolachlor			-----	n.d.	n.d.	0.10			
Metribuzin			-----	n.d.	n.d.	0.10			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 22.9 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 168 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 67. Summary of water quality conditions monitored in Conestoga Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site CONLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	24	1230.1	1230.5	1225.8	1232.8	-----	-----	-----
Water Temperature (C)	0.1	123	22.8	22.9	15.6	28.9	32	0	0%
Dissolved Oxygen (mg/l)	0.1	123	7.6	7.5	3 9	15.2	≥ 5.0	10	8%
Dissolved Oxygen (% Sat.)	0.1	118	89.8	88.1	46 2	186.7	-----	-----	-----
Specific Conductance (umho/cm)	1	118	407	402	323	521	-----	-----	-----
pH (S.U.)	0.1	118	8.5	8.6	7.6	9.1	≥6.5 & ≤9.0	5	4%
Turbidity (NTUs)	0.1	75	47.4	44.7	5 1	98.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	85	379	370	294	505	-----	-----	-----
Secchi Depth (in.)	1	24	17	16	8	44	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	35	18	17	5	37	16[(1)]	18	51%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [(1)] Nutrient criteria.

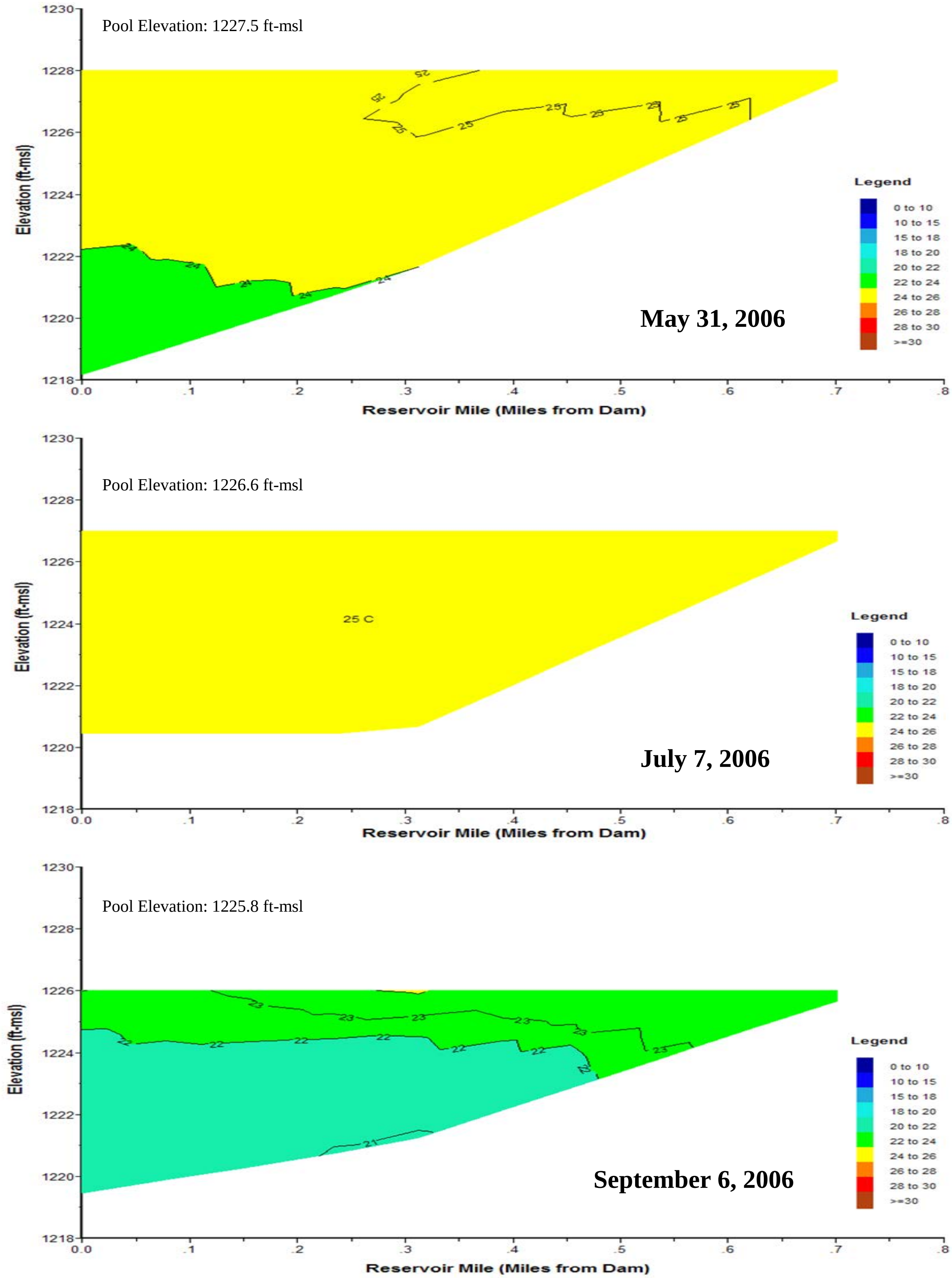

Plate 68. Longitudinal water temperature (°C) contour plots of Conestoga Reservoir based on depth-profile water temperatures measured at sites CONLKND1 and CONLKMLN1 in May, July, and September 2006.

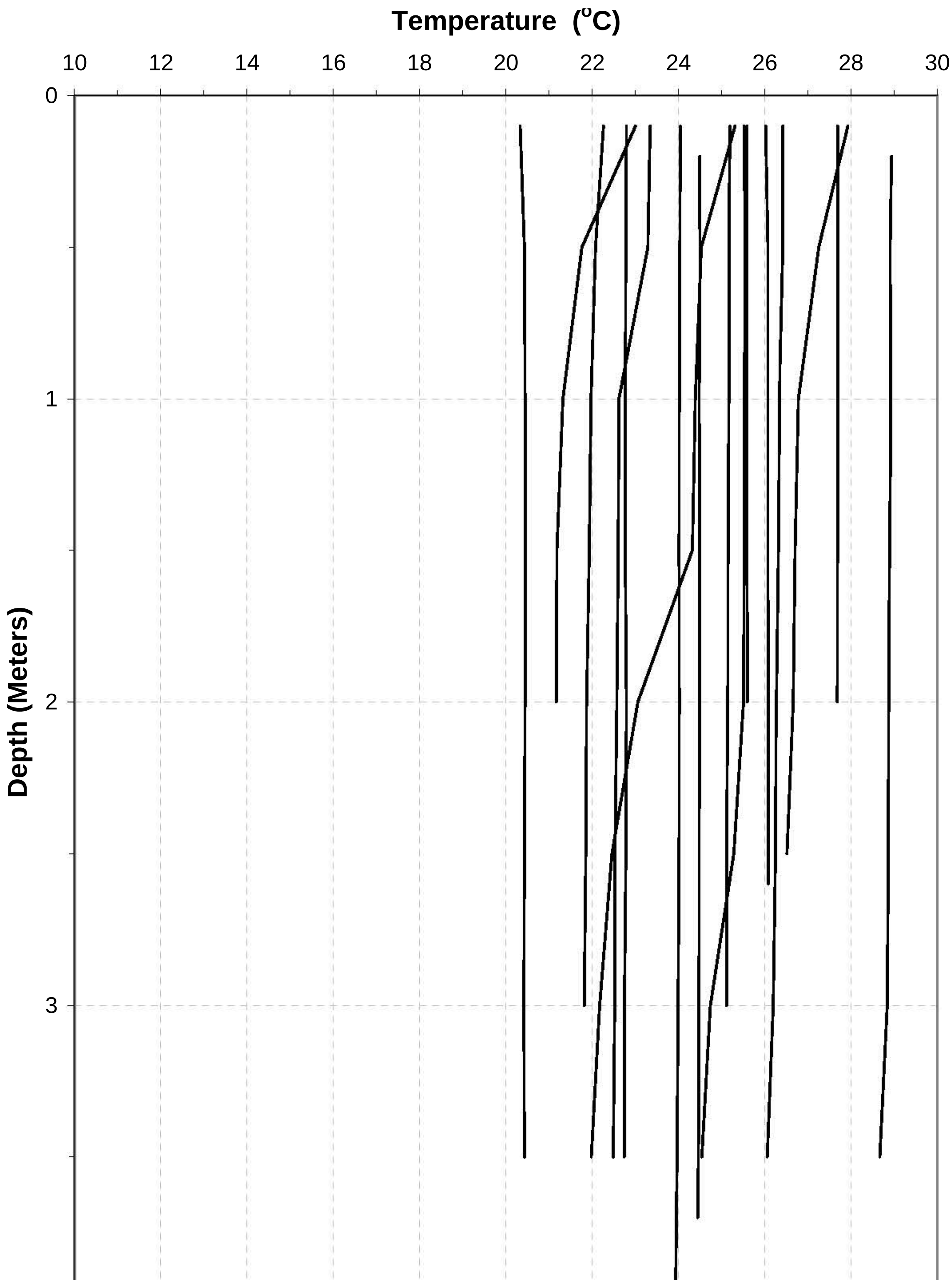

Plate 69. Temperature depth profiles for Conestoga Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., CONLKND1) during the summer over the 5-year period of 2002 to 2006.

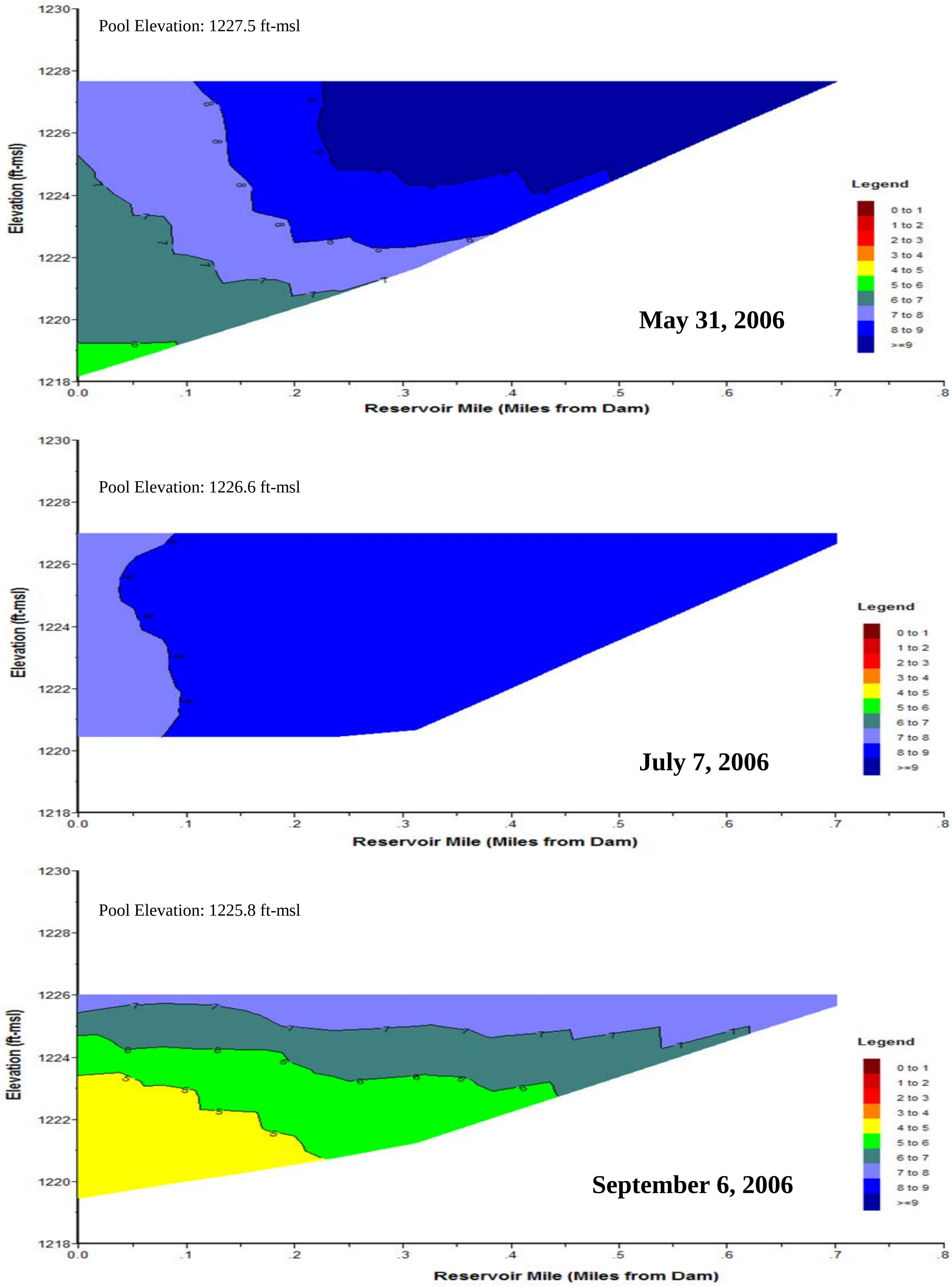

Plate 70. Longitudinal dissolved oxygen (mg/l) contour plots of Conestoga Reservoir based on depth-profile dissolved oxygen concentrations measured at sites CONLKND1 and CONLKMLN1 in May, July, and September 2006.

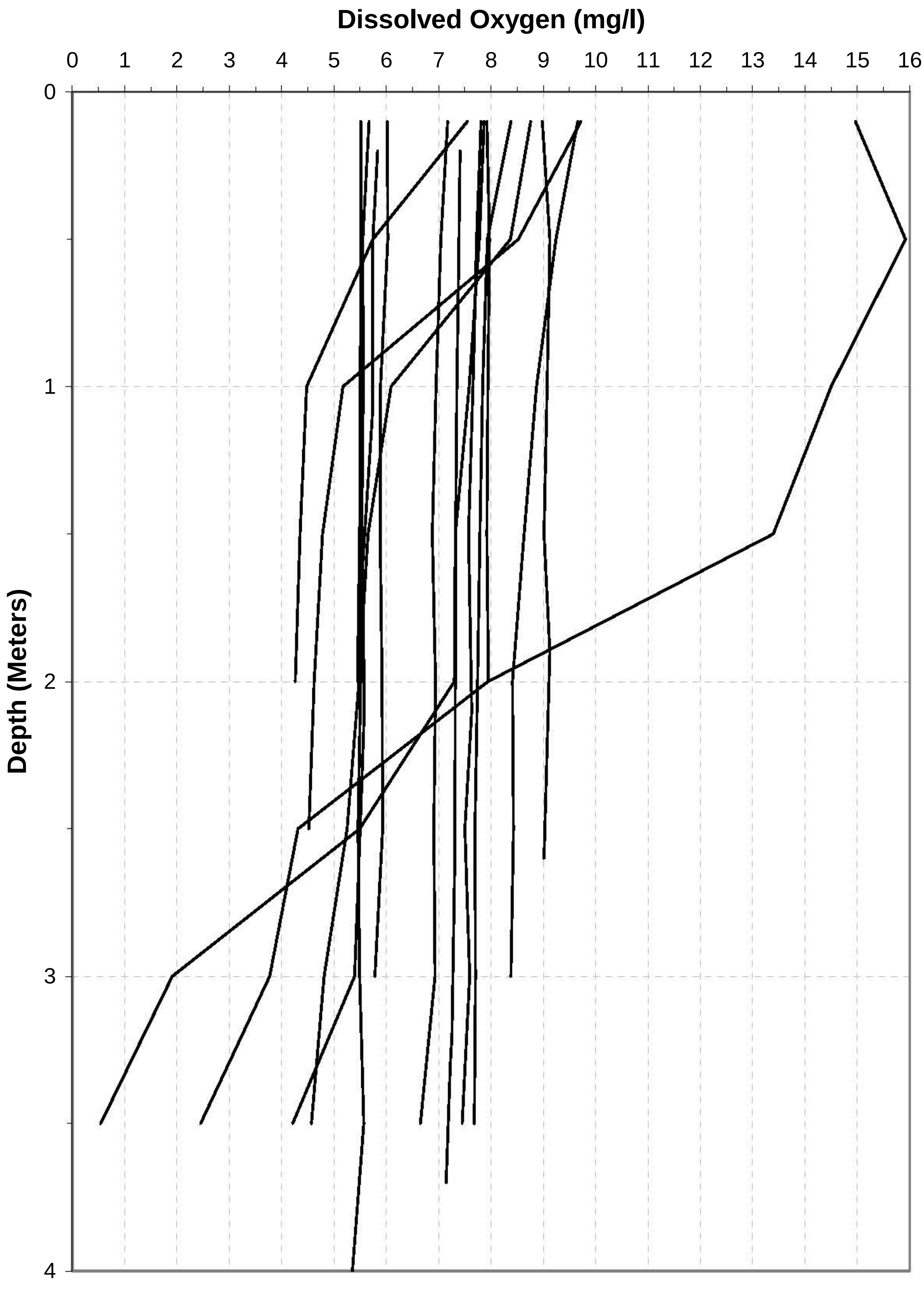

Plate 71. Dissolved oxygen depth profiles for Conestoga Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., CONLKND1) during the summer over the 5-year period of 2002 to 2006.

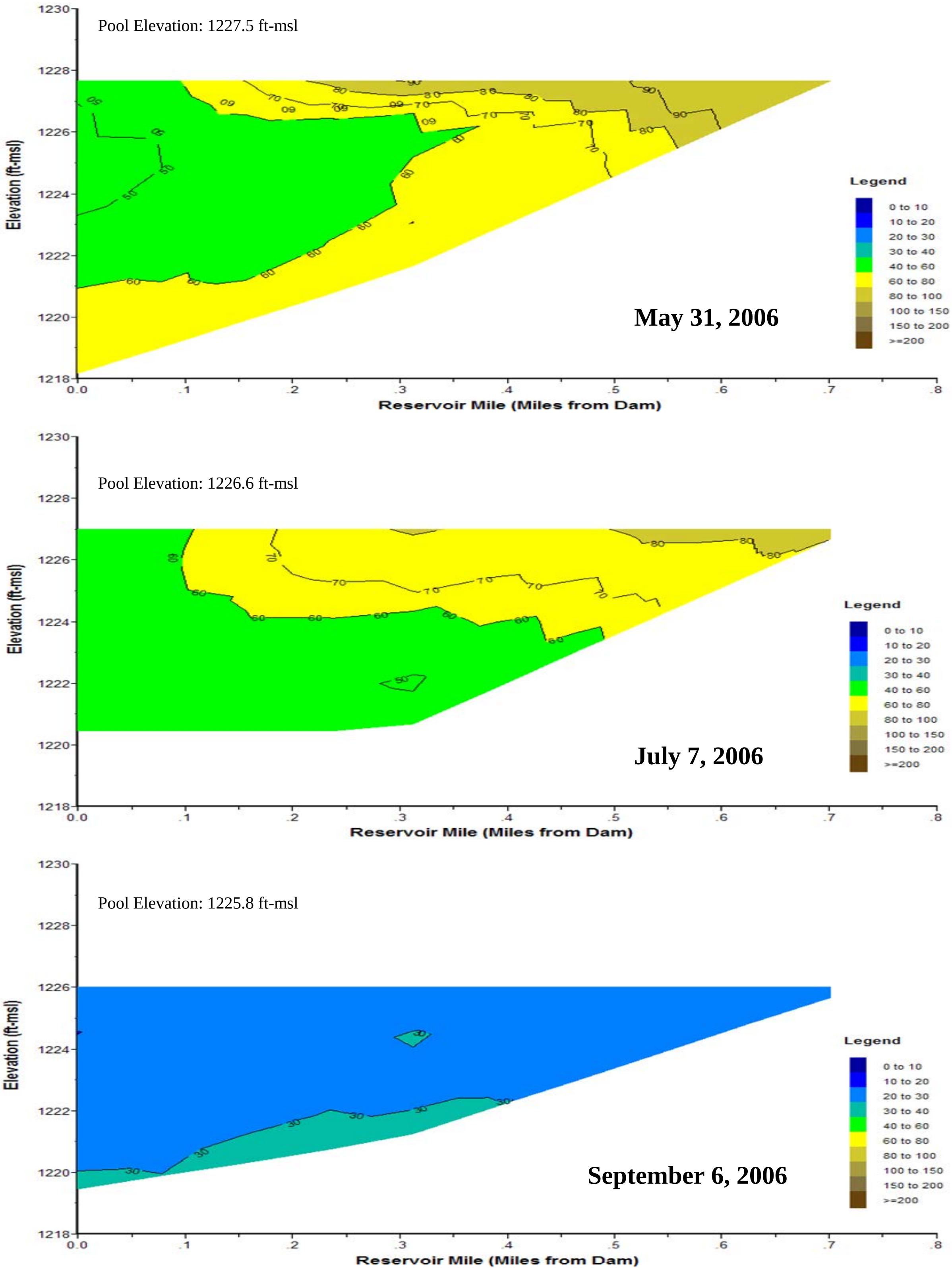

Plate 72. Longitudinal turbidity (NTU) contour plots of Conestoga Reservoir based on depth-profile turbidity levels measured at sites CONLKND1 and CONLKMLN1 in May, July, and September 2006.

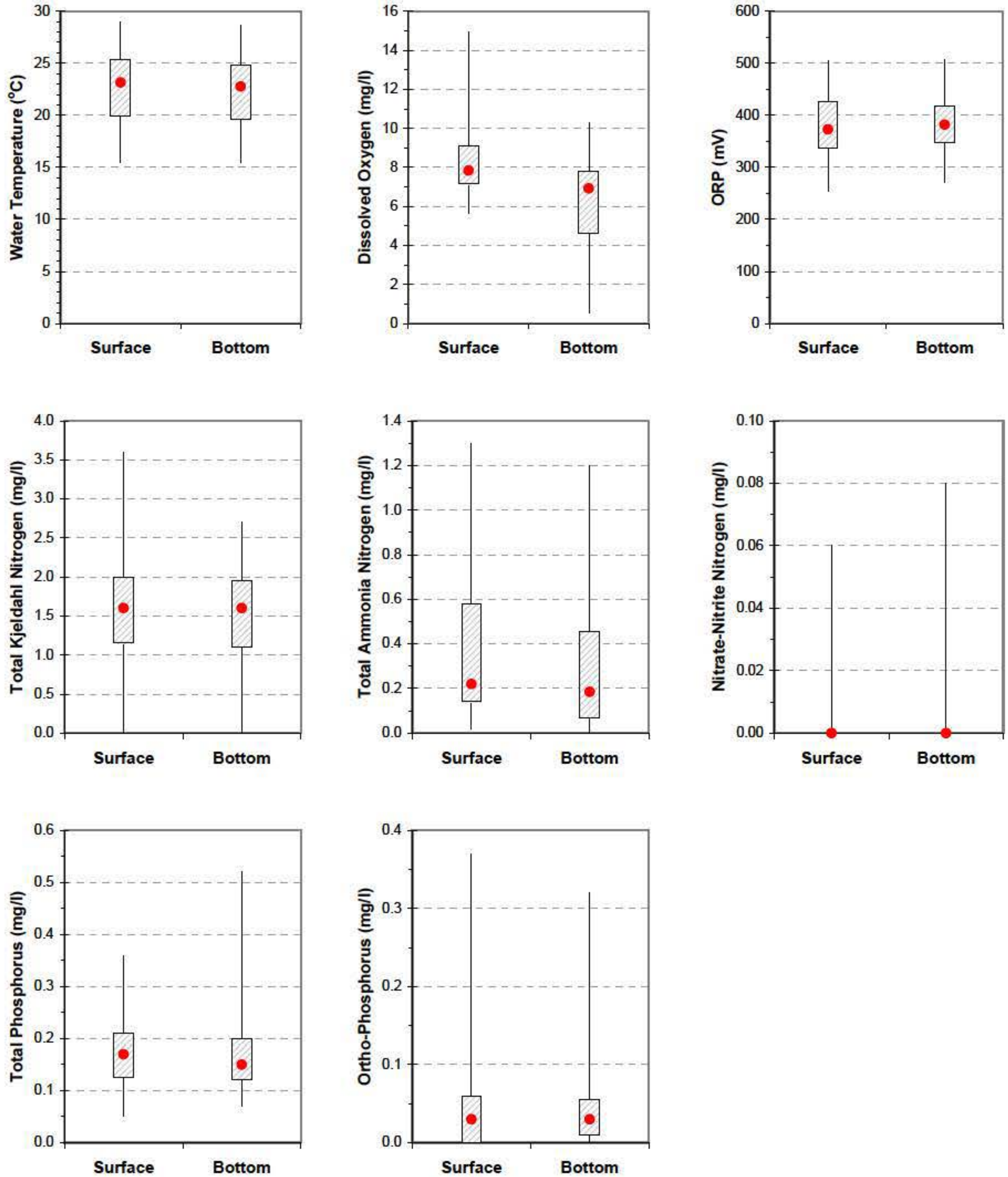

Plate 73. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Conestoga Reservoir at site CONLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

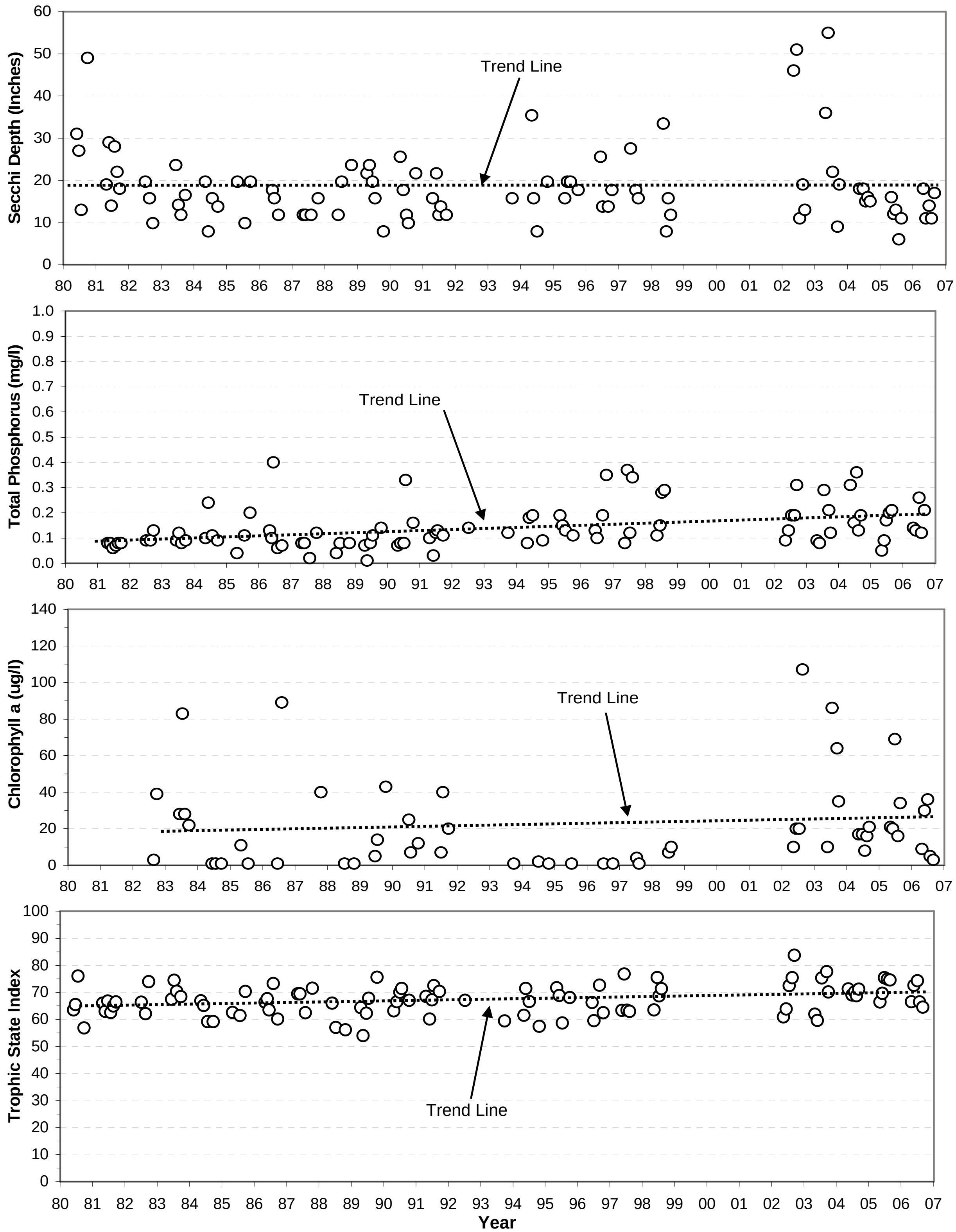

Plate 74. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Conestoga Reservoir at the near-dam, ambient site (i.e., site CONLKND1) over the 27-year period of 1980 to 2006.

Plate 75. Summary of runoff water quality conditions monitored in the main tributary inflow to Conestoga Reservoir at monitoring site CONNF1 during the period 2002 through 2006**.**

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Turbidity (NTUs)	0.1	2	1,394	1394	387	2,400	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	7	3.8	3.3	1.4	6.7	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	7	1.15	0.94	0.14	2.17		-----	-----
Phosphorus, Total (mg/l)	0.01	7	1.50	1.28	0.80	2.50	-----	-----	-----
Suspended Solids, Total (mg/l)	4	7	868	344	98	2,560	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	7	0.74	0.24	0.11	3.74	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	7	5.84	3.54	0.23	13.75	330(1), 12(2)	0, 1	0%, 14%
Metolachlor, Total (ug/l)***	0.05	7	2.56	1.21	0.42	9.02	390(1), 100(2)	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.

** (1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

*** Immunoassay analysis.

Plate 76. Summary of water quality conditions monitored in Holmes Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site HOLLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1242.2	1242.3	1242.0	1242.4	-----	-----	-----
Water Temperature (C)	0.1	42	22.8	23.2	15.5	28.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	42	7.7	8.6	0.3	15.7	≥ 5.0	11	26%
Dissolved Oxygen (% Sat.)	0.1	35	92.4	94.0	3.2	202.3	-----	-----	-----
Specific Conductance (umho/cm)	1	42	407	396	369	694	-----	-----	-----
pH (S.U.)	0.1	42	8.3	8.5	6.5	9.2	≥6.5 & ≤9.0	4	10%
Turbidity (NTUs)	0.1	42	8.8	4.4	1.2	46.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	42	344	351	60	469	-----	-----	-----
Secchi Depth (in.)	1	5	50	44	22	108	-----	-----	-----
Alkalinity, Total (mg/l)	7	10	123	110	110	160	-----	-----	-----
Ammonia, Total (mg/l)	0.01	10	-----	0.01	n.d.	0.25	3.20 [1,2], 0.62 [1,3]	0	0%
Chlorophyll *a* (ug/l) – Lab Determined	1	5	11.2	5	3	35	44[5]	0	0%
Hardness, Total (mg/l)	0.4	1	112	112	112	112	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	10	1.14	1.10	0.60	1.90	-----	-----	-----
Nitrogen, Total (mg/)	0.1	10	1.14	1.10	0.60	1.90	1.46[5]	2	20%
Nitrate-Nitrite N, Total (mg/l)	0.02	10	-----	n.d.	n.d.	n.d.	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	10	0.09	0.08	0.04	0.23	0.134[5]	1	10%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	10	-----	n.d.	n.d.	0.14	-----	-----	-----
Suspended Solids, Total (mg/l)	4	10	-----	6	n.d.	15	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	1	6	6	6	6	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	6.6[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	650[2], 85[3]	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	2	15.0[2], 9.9[3]	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	73[2], 2.9[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	1	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	1	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	8	723[2], 80[3]	0	0%
Selenium, Total (ug/l)	2	1	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	4 2[2]	0	0%
Thallium (ug/l)	6	1	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	7	129[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	1.9	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	5	-----	n.d.	n.d.	0.05	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	5	0.42	0.46	0.24	0.59	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	5	-----	n.d.	n.d.	0.10	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	1					*****	0	0%
Atrazine			1.70	1.70	1.70	1.70			
Oxyfluorfen			0.86	0.86	0.86	0.86			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.5 and 23.2 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 112 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 77. Summary of water quality conditions monitored in Holmes Reservoir at the mid-lake, deepwater ambient monitoring location in the north arm (i.e., site HOLLKMLN1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1242.2	1242.3	1242.0	1242.4	-----	-----	-----
Water Temperature (C)	0.1	34	23.2	24.8	15 5	28.3	32	0	0%
Dissolved Oxygen (mg/l)	0.1	34	9.0	9.2	1.09	16.6	≥ 5.0	4	12%
Dissolved Oxygen (% Sat.)	0.1	28	112.5	101.7	13.7	213.0	-----	-----	-----
Specific Conductance (umho/cm)	1	34	396	395	364	436	-----	-----	-----
pH (S.U.)	0.1	34	8.6	8.6	7 5	9.2	≥6.5 & ≤9.0	5	15%
Turbidity (NTUs)	0.1	34	8.5	4.0	1.0	27.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	34	357	329	285	500	-----	-----	-----
Secchi Depth (in.)	1	5	54	44	24	120	-----	-----	-----
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.			
Alachlor, Total (ug/l)**	0.05	3	-----	n.d.	n.d.	0.06	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)**	0.05	3	0.40	0.43	0.22	0.54	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)**	0.05	3	-----	n.d.	n.d.	0.05	390(2), 100(3)	0	0%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

Plate 78. Summary of water quality conditions monitored in Holmes Reservoir at the mid-lake, deepwater ambient monitoring location in the south arm (i.e., site HOLLKMLS1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1242.2	1242.3	1242.0	1242.4	-----	-----	-----
Water Temperature (C)	0.1	35	23.1	24.6	15 1	28.3	32	0	0%
Dissolved Oxygen (mg/l)	0.1	34	7.7	8.5	0.4	17.4	≥ 5.0	12	35%
Dissolved Oxygen (% Sat.)	0.1	28	93.4	94.4	4.4	226.5	-----	-----	-----
Specific Conductance (umho/cm)	1	35	385	385	300	423	-----	-----	-----
pH (S.U.)	0.1	35	8.4	8.5	6 9	9.4	≥6.5 & ≤9.0	4	11%
Turbidity (NTUs)	0.1	28	8.8	6.0	1 9	24.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	35	353	356	116	528	-----	-----	-----
Secchi Depth (in.)	1	5	45	42	27	75	-----	-----	-----
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)**	0.05	3	-----	n.d.	n.d.	n.d.	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)**	0.05	3	0.36	0 39	0.22	0.47	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)**	0.05	3	-----	n.d.	n.d.	n.d.	390(2), 100(3)	0	0%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

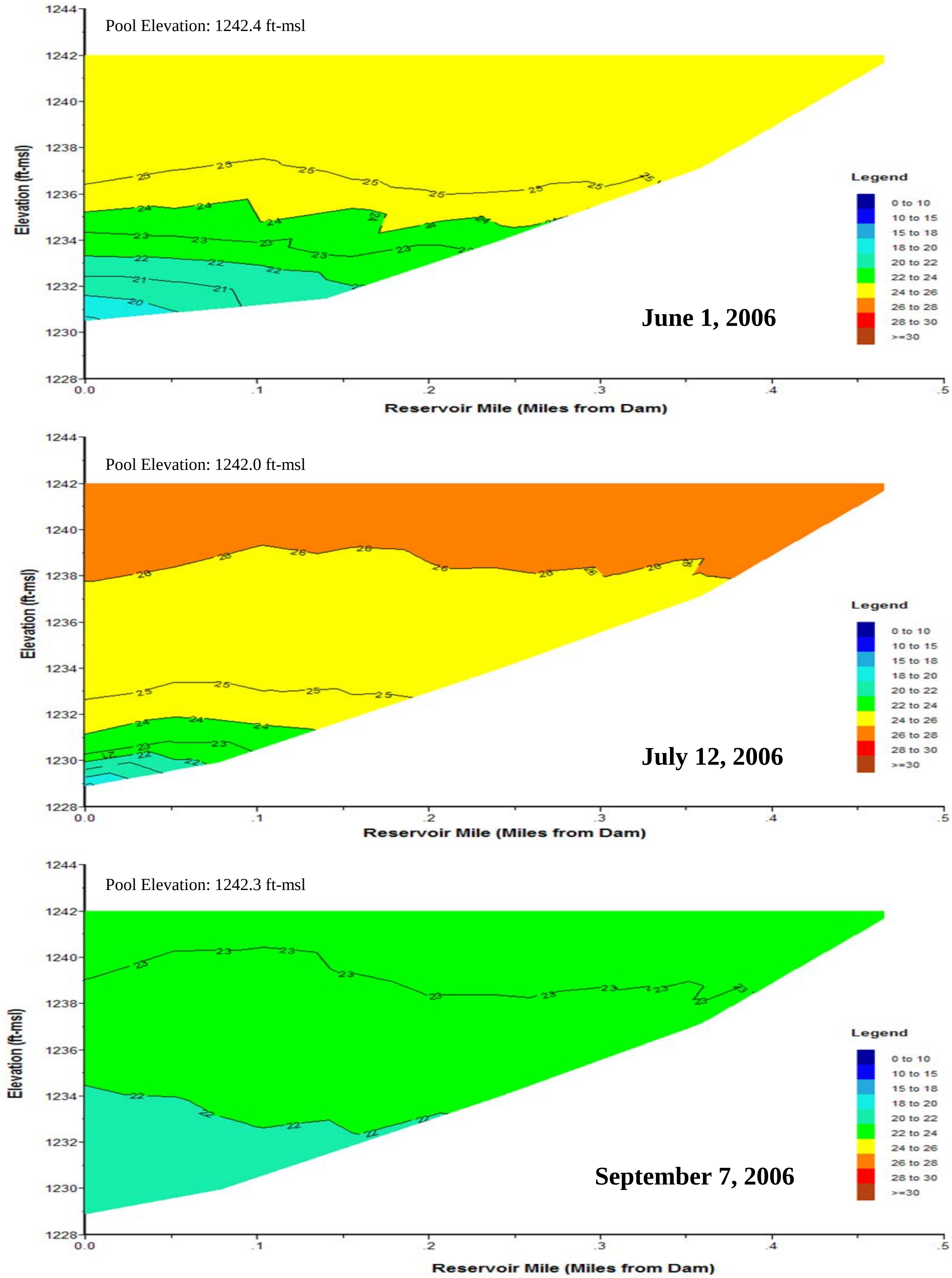

Plate 79. Longitudinal water temperature (°C) contour plots of Holmes Reservoir through the north arm based on depth-profile water temperatures measured at sites HOLLKND1 and HOLLKMLN1 in June, July, and September 2006.

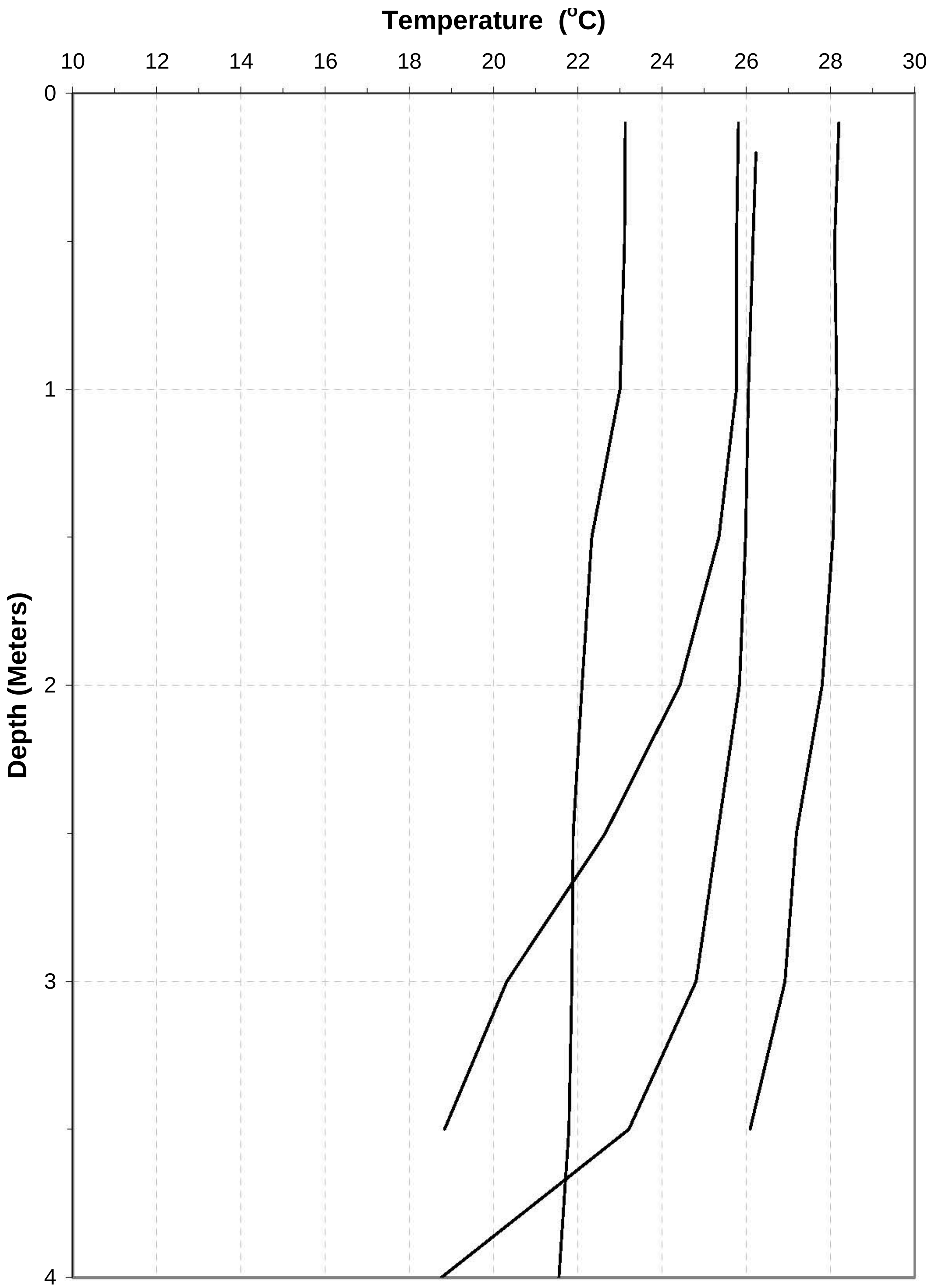

Plate 80. Temperature depth profiles for Holmes Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., HOLLKND1) during the summer of 2006.

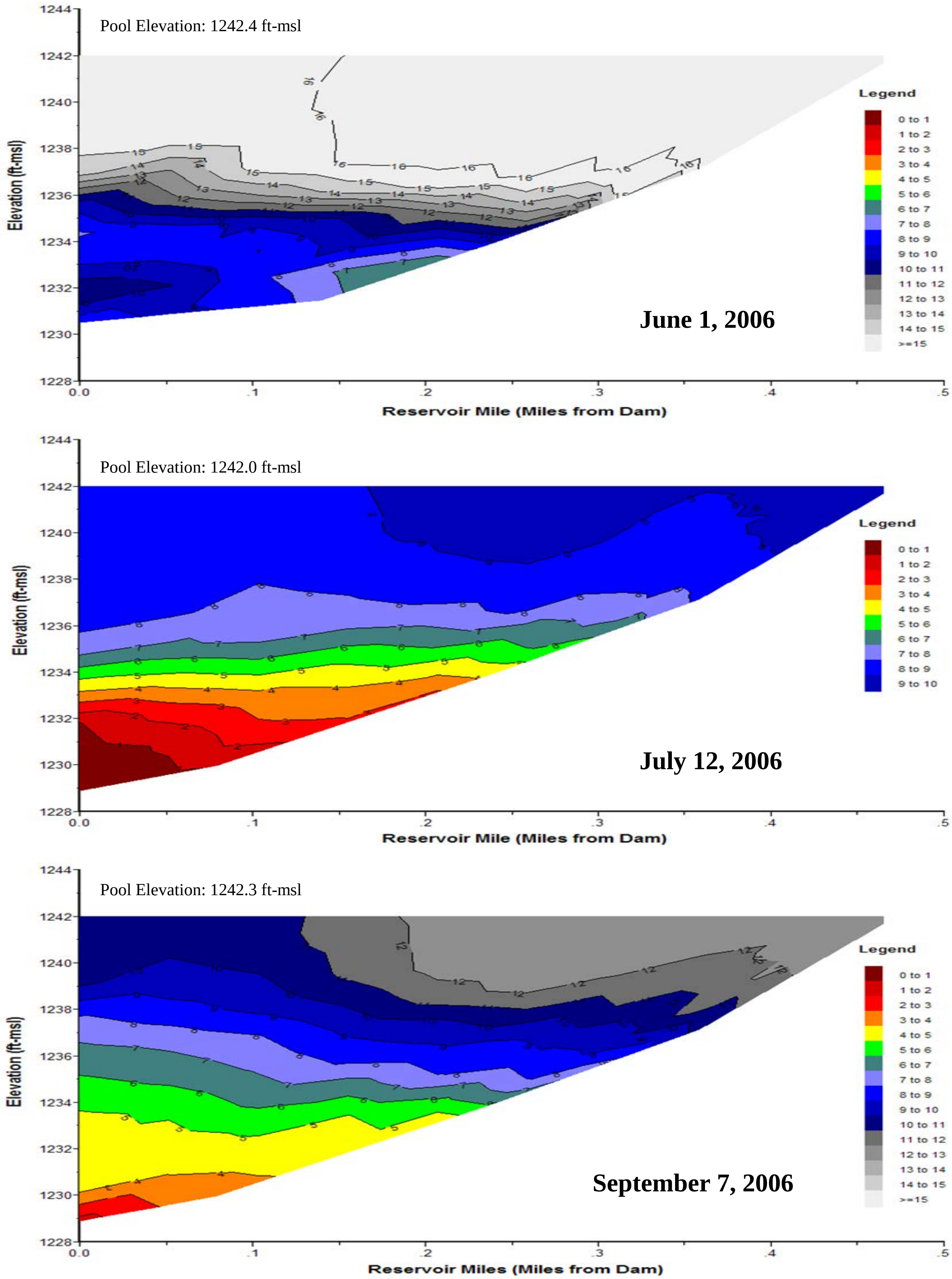

Plate 81. Longitudinal dissolved oxygen (mg/l) contour plots of Holmes Reservoir through the north arm based on depth-profile dissolved oxygen concentrations measured at sites HOLLKND1 and HOLLKMLN1 in June, July, and September 2006.

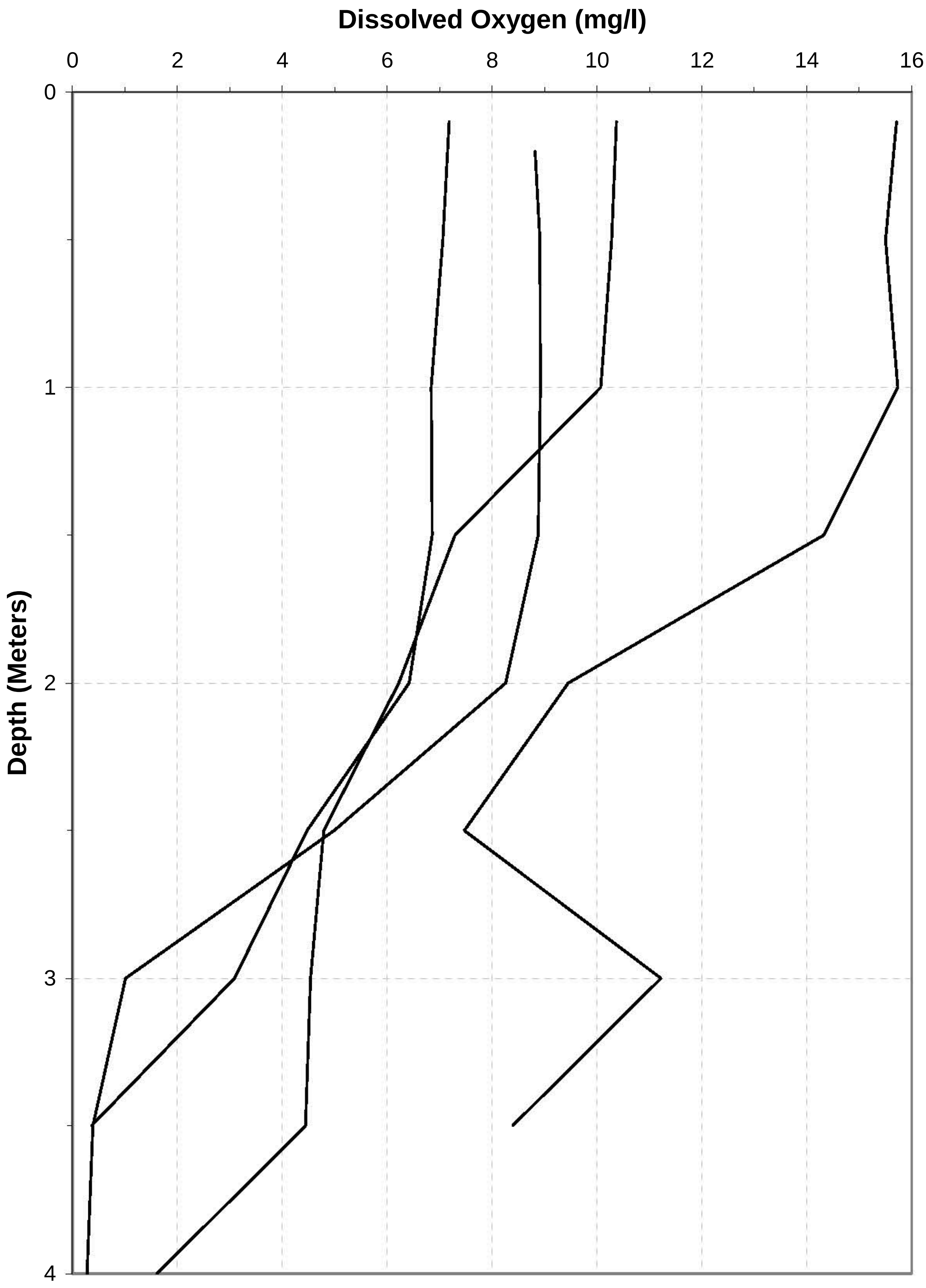

Plate 82. Dissolved oxygen depth profiles for Holmes Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., HOLLKND1) during the summer of 2006.

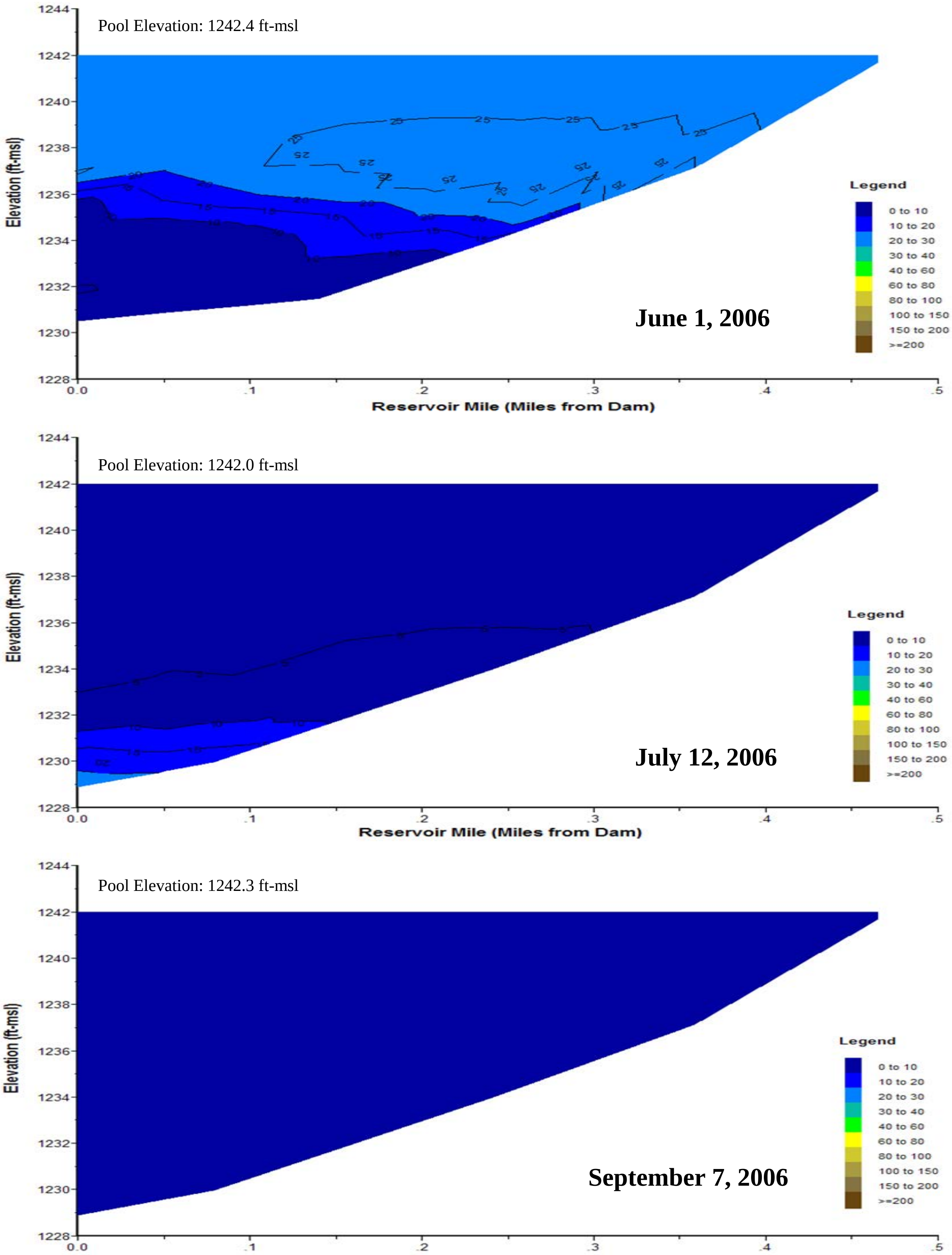

Plate 83. Longitudinal turbidity (NTU) contour plots of Holmes Reservoir through the north arm based on depth-profile turbidity levels measured at sites HOLLKND1 and HOLLKMLN1 in June, July, and September 2006.

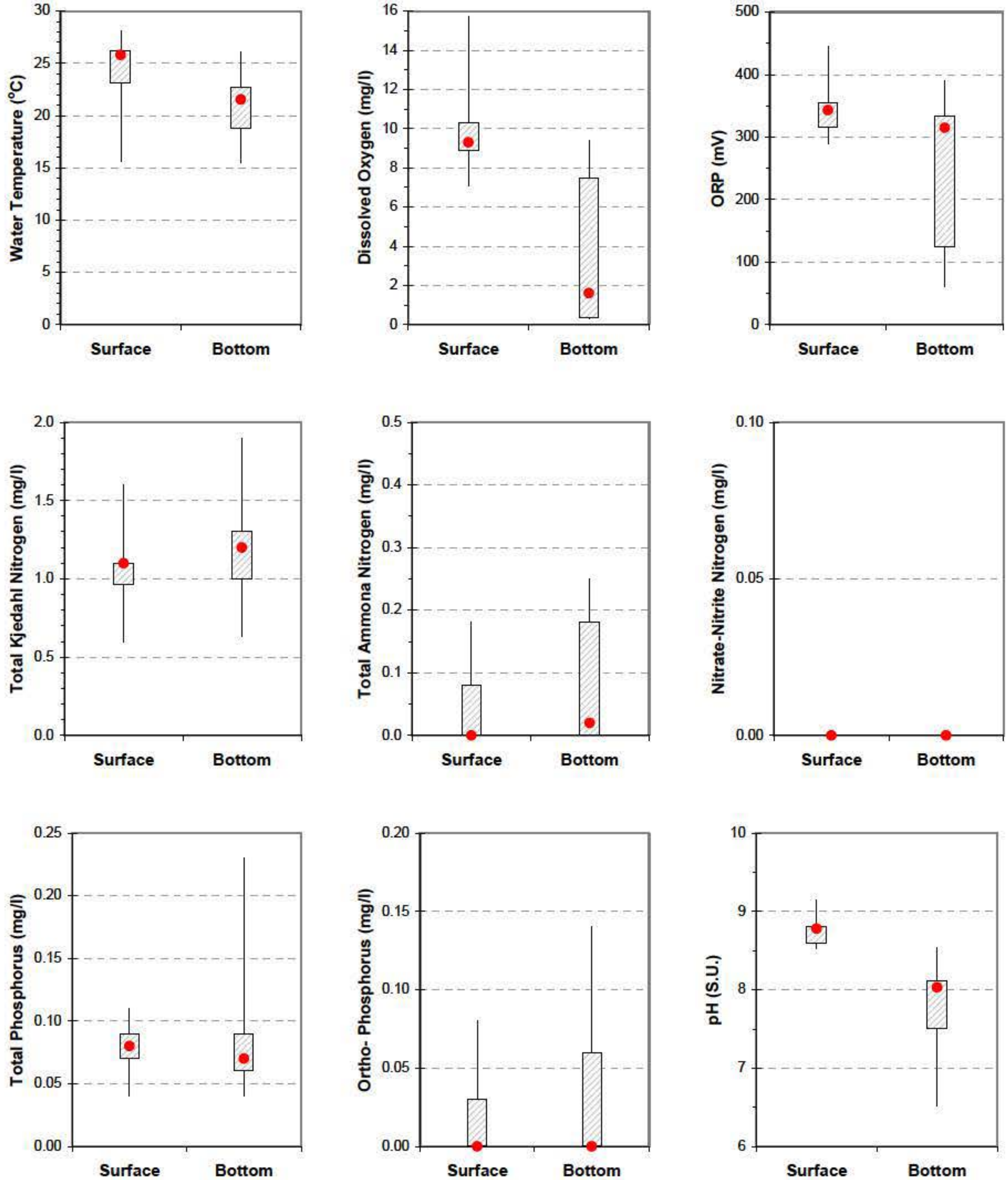

Plate 84. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Holmes Reservoir at site HOLLKND1 during the summer months of 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

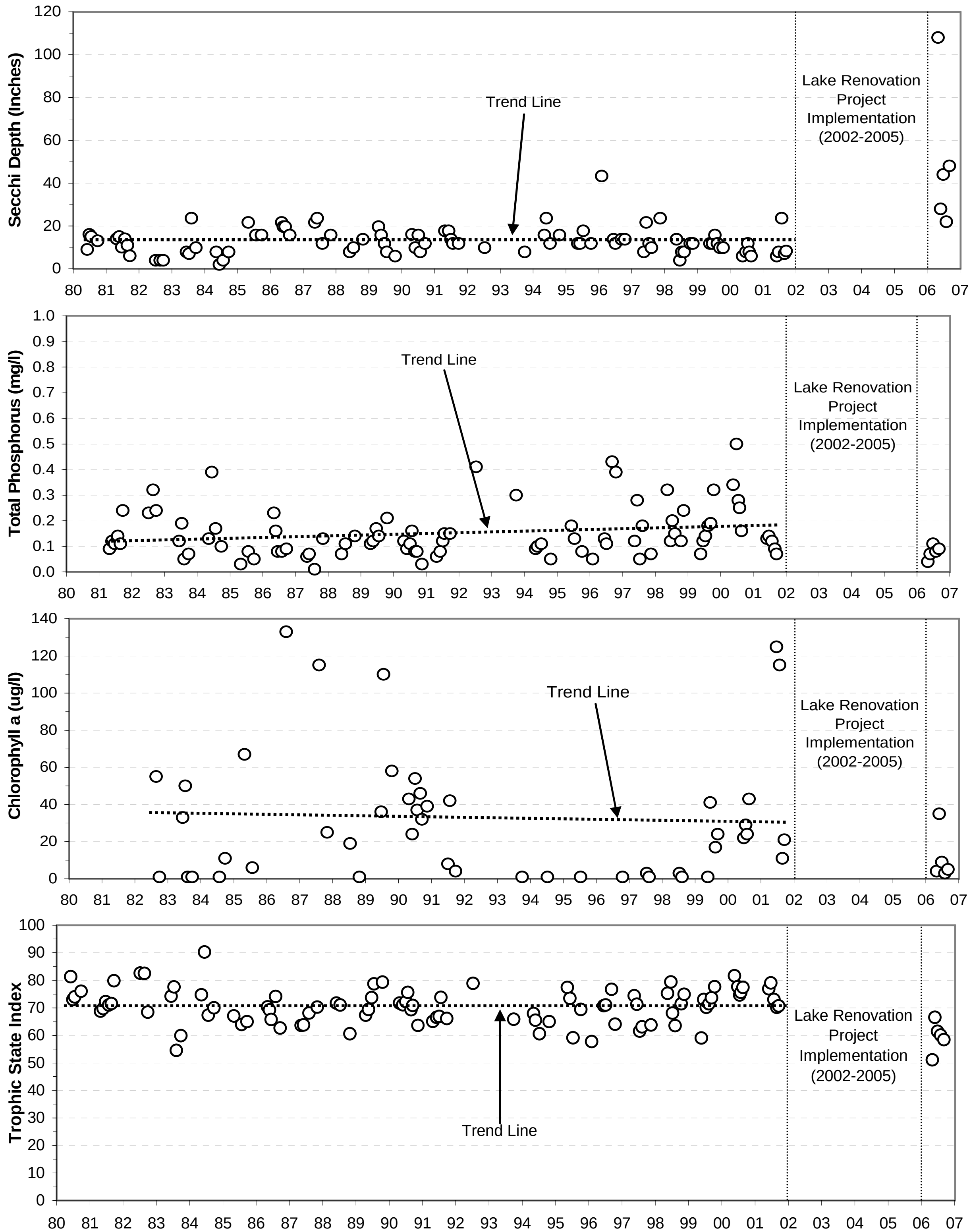

Plate 85. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Holmes Reservoir at the near-dam, ambient site (i.e., site HOLLKND1) over the 27-year period of 1980 to 2006. (Note: lake renovation project implemented from 2002 through 2005).

Plate 86. Summary of runoff water quality conditions monitored in the main west tributary inflow to Holmes Reservoir at monitoring site HOLNFSTH1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Kjeldahl N, Total (mg/l)	0.1	9	2.0	2.0	1.6	2.9	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	0.84	0.69	0.36	1.59	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	9	0.52	0.50	0.32	0.82	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	239	216	13	946	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	6	0.06	0.06	0.05	0.08	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	7	0.31	0.31	0.05	0.86	330(1), 12(2)	0	0%
Metolachlor, Total (ug/l)***	0.05	7	0.14	0.14	0.05	0.24	390(1), 100(2)	0	0%
E. coli (cfu/100ml)	1	15	5440	4352	186	14,136	-----	-----	-----

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 87. Summary of runoff water quality conditions monitored in the main east tributary inflow to Holmes Reservoir at monitoring site HOLNFEST1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Kjeldahl N, Total (mg/l)	0.1	12	2.4	2.0	0.8	5.9	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	11	0.62	0.41	0.15	2.46	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	12	0.61	0.54	0.14	2.15	-----	-----	-----
Suspended Solids, Total (mg/l)	4	12	476	210	13	3,240	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	9	0.13	0.07	0.05	0.31	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	10	1.01	0.44	0.05	6.38	330(1), 12(2)	0	0%
Metolachlor, Total (ug/l)***	0.05	10	0.25	0.14	0.05	1.31	390(1), 100(2)	0	0%
E. coli (cfu/100ml)	1	16	3,626	2,454	13	10,462	-----	-----	-----

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 88. Summary of water quality conditions monitored in Olive Creek Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site OCRLKND1) from May to September during the 4-year period 2003 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	20	1330.6	1330.2	1328.1	1334.2	-----	-----	-----
Water Temperature (C)	0.1	95	22.2	22.5	15.9	27.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	95	7.1	7.2	0.5	14.3	≥ 5.0	14	15%
Dissolved Oxygen (% Sat.)	0.1	92	83.9	82.0	6.9	167.7	-----	-----	-----
Specific Conductance (umho/cm)	1	92	239	236	171	335	-----	-----	-----
pH (S.U.)	0.1	92	8.6	8.4	7.4	10.2	≥6.5 & ≤9.0	36	39%
Turbidity (NTUs)	0.1	67	64.8	51.8	23.4	123.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	78	371	370	179	461	-----	-----	-----
Secchi Depth (in.)	1	20	12	10	2	25	-----	-----	-----
Alkalinity, Total (mg/l)	7	37	128	130	87	203	-----	-----	-----
Ammonia, Total (mg/l)	0.01	32	-----	0.20	n.d.	1.20	3.88 [1,2], 0.77 [1,3]	4	13%
Chlorophyll *a* (ug/l) – Field Probe	1	30	19	18	9	34	16[5]	19	63%
Chlorophyll *a* (ug/l) – Lab Determined	1	19	31	14	1	170	16[5]	8	42%
Hardness, Total (mg/l)	0.4	8	115	115	79	155	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	37	2.4	2.0	0.5	6.3	-----	-----	-----
Nitrogen, Total (mg/)	0.1	37	2.6	2.4	0.5	6.3	1.54[5]	28	76%
Nitrate-Nitrite N, Total (mg/l)	0.02	37	-----	n.d.	n.d.	1.50	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	37	0.32	0.31	0.02	0.84	0.143[5]	31	84%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	37	0.14	0.10	n.d.	0.65	-----	-----	-----
Suspended Solids, Total (mg/l)	4	37	31	28	11	56	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	33	29	16	59	340[2], 16.7[3,4]	0, 3	0%, 75%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	6.8[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	664[2], 86[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	2	15.0[2], 10.0[3]	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	75[2], 2.9[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	527[2], 59[3]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	4.4[2]	0	0%
Thallium (ug/l)	6	2	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	133[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	9	-----	n.d.	0.8	3.2	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	19	0.26	0.27	0.06	0.54	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	20	3.43	2.20	n.d.	13.3	330[2], 12[3]	0, 1	0%, 5%
Metolachlor, Total (ug/l)***	0.05	19	0.60	0.29	0.09	2.12	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	4					*****	0	0%
Acetochlor			-----	0.20	n.d.	0.65			
Atrazine			-----	1.28	n.d.	7.20			
Metolachlor			-----	n.d.	n.d.	1.30			
Metribuzin			-----	n.d.	n.d.	0.70			
Propazine			-----	n.d.	n.d.	0.10			
Simazine			-----	n.d.	n.d.	0.20			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 22.5 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 115 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 89. Summary of water quality conditions monitored in Olive Creek Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site OCRLKML1) from May to September during the 4-year period 2003 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	19	1330.7	1330.4	1328 1	1334.2	-----	-----	-----
Water Temperature (C)	0.1	73	21.9	22.2	15.6	27.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	73	7.4	7.6	3.6	12.2	≥ 5.0	4	12%
Dissolved Oxygen (% Sat.)	0.1	70	88.0	83.9	42.0	142.1	-----	-----	-----
Specific Conductance (umho/cm)	1	70	241	238	171	321	-----	-----	-----
pH (S.U.)	0.1	70	8.6	8.4	7.4	10.2	≥6.5 & ≤9.0	5	15%
Turbidity (NTUs)	0.1	49	63.7	53.8	22 1	125.8	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	57	375	377	286	472	-----	-----	-----
Secchi Depth (in.)	1	19	11	10	3	22	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	21	21	24	7	33	16[(5)]	11	52%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

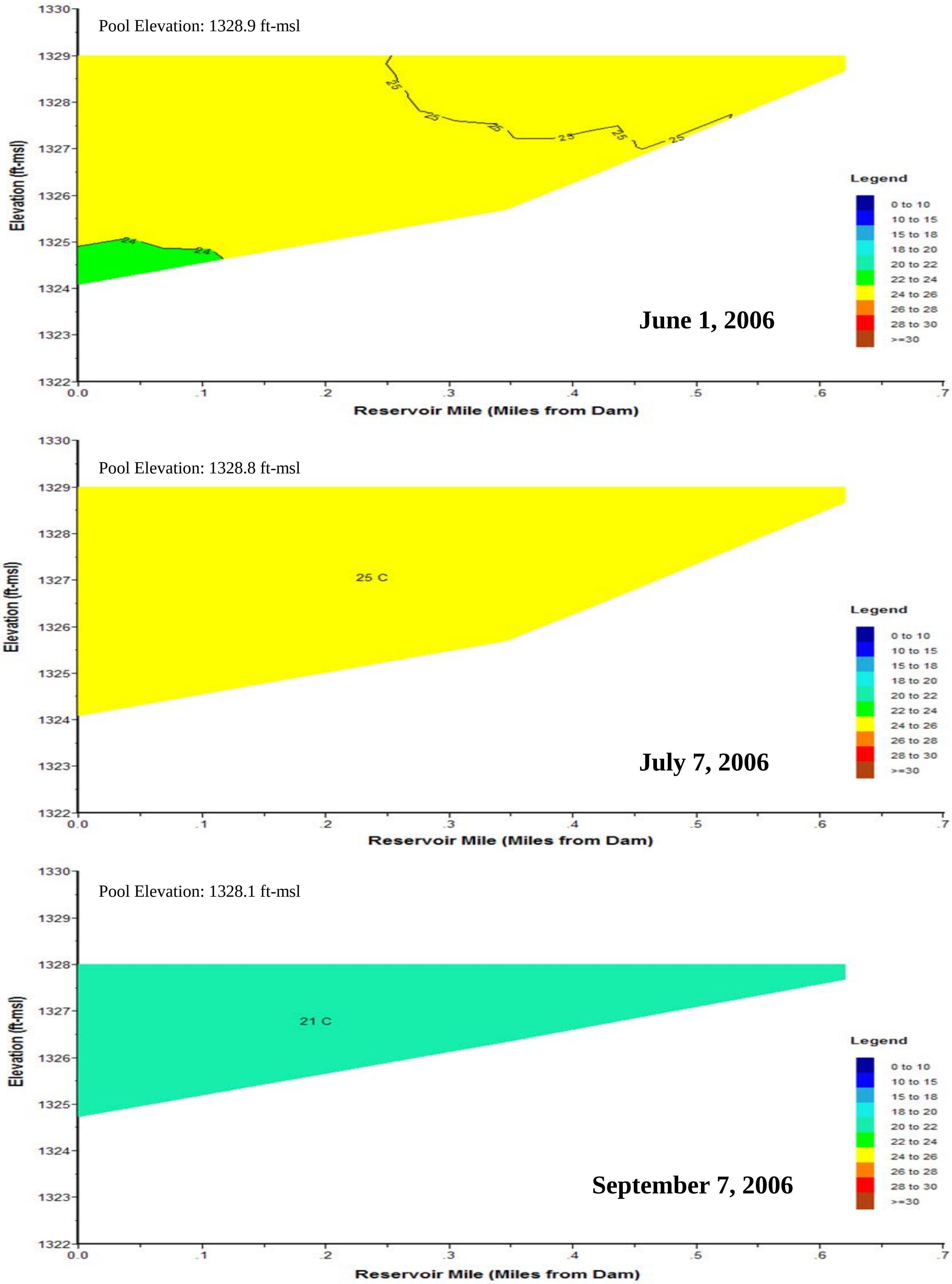

Plate 90. Longitudinal water temperature (°C) contour plots of Olive Creek Reservoir based on depth-profile water temperatures measured at sites OCRLKND1 and OCRLKML1 in June, July, and September 2006.

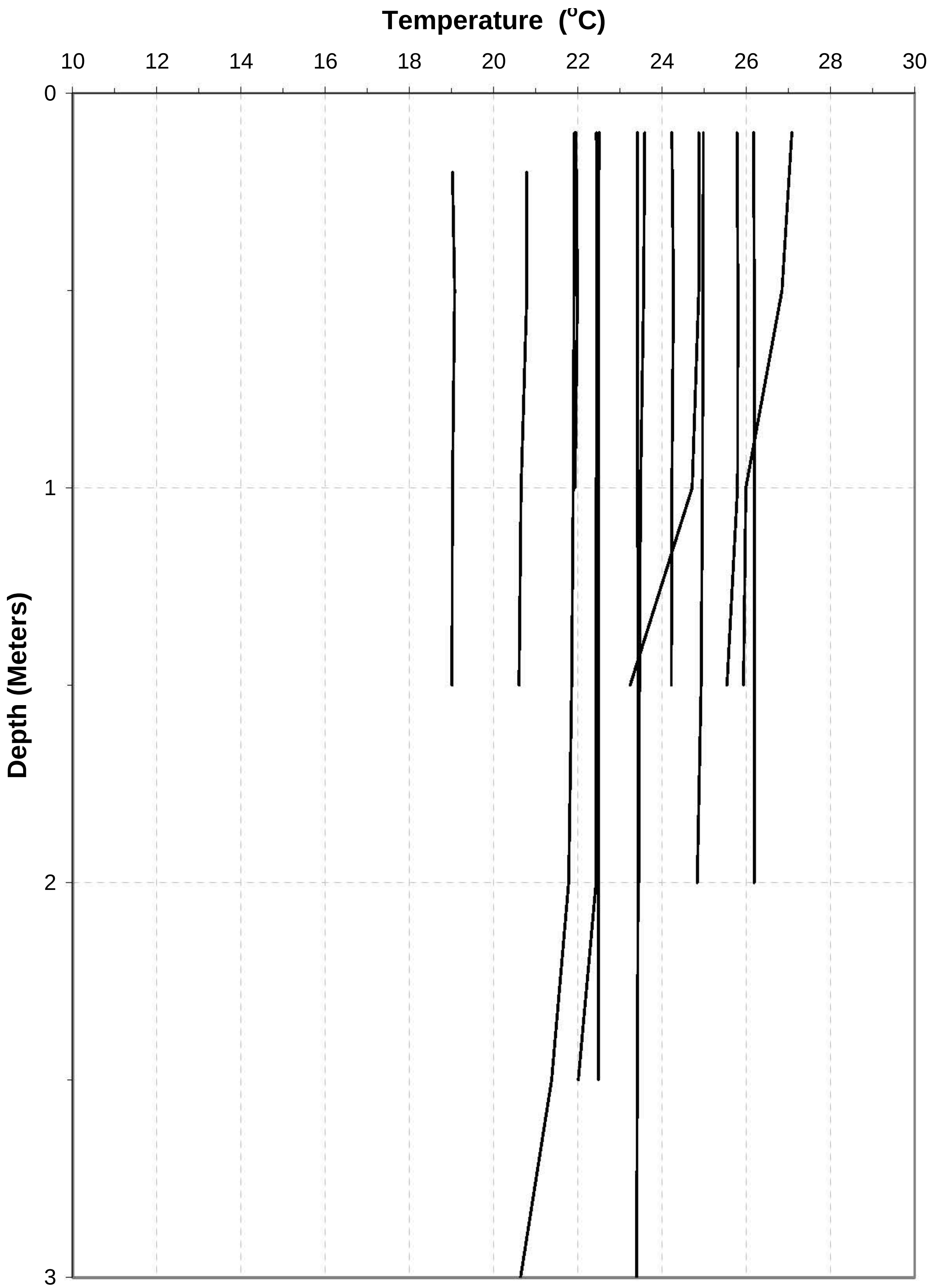

Plate 91. Temperature depth profiles for Olive Creek Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., OCRLKND1) during the summer over the 4-year period of 2003 through 2006.

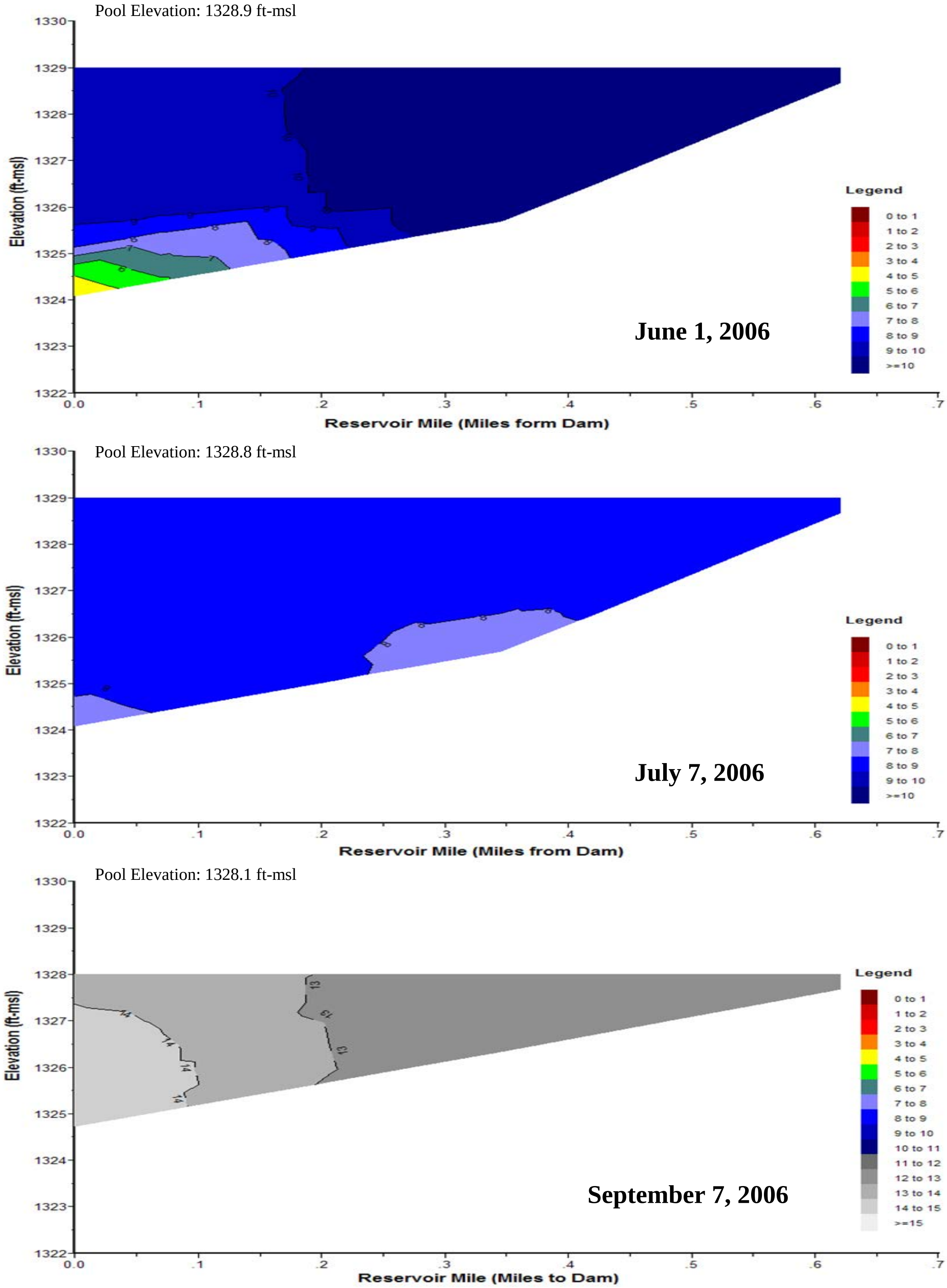

Plate 92. Longitudinal dissolved oxygen (mg/) contour plots of Olive Creek Reservoir based on depth-profile water temperatures measured at sites OCRLKND1 and OCRLKML1 in June, July, and September 2006.

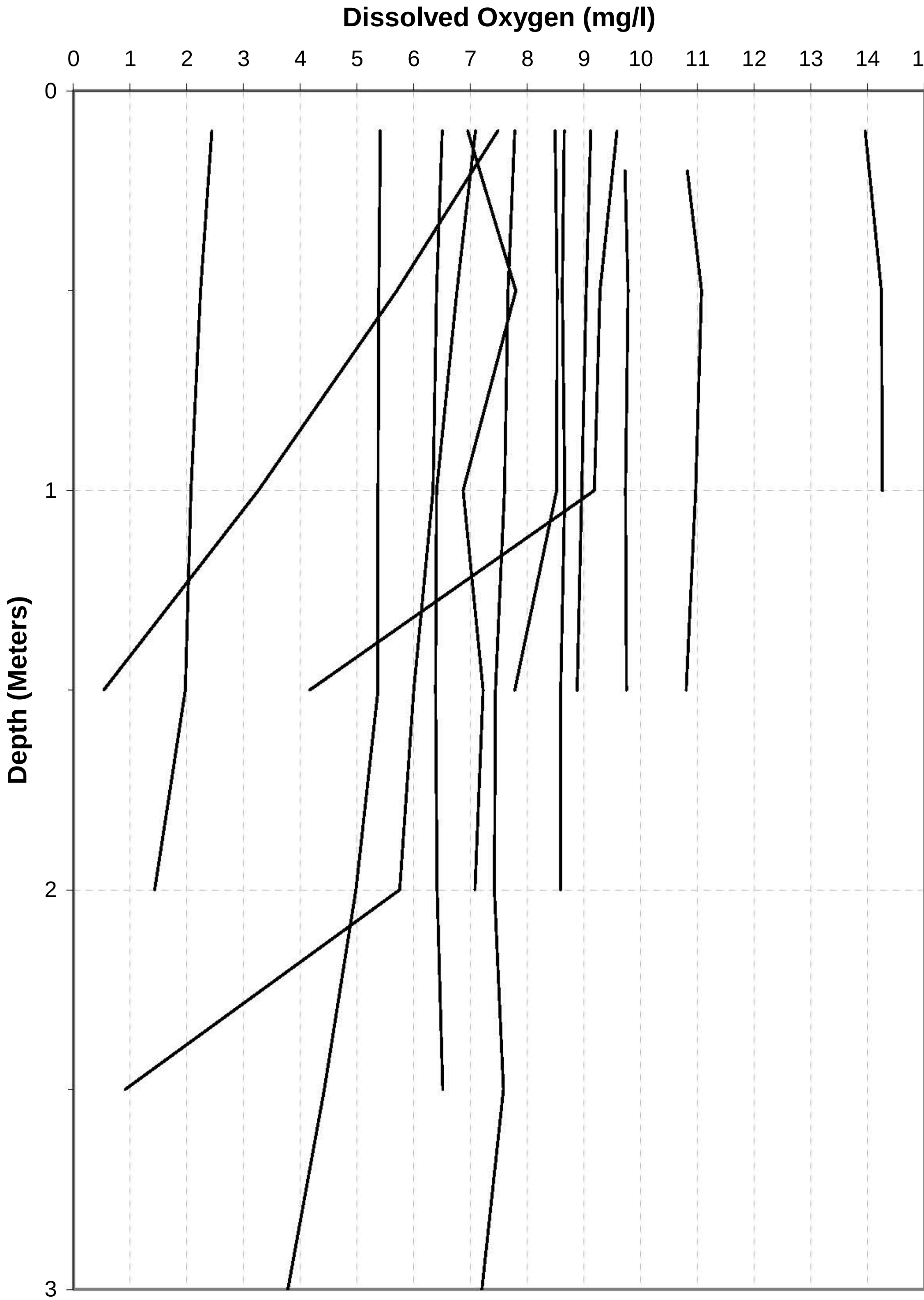

Plate 93. Dissolved Oxygen depth profiles for Olive Creek Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., OCRLKND1) during the summer over the 4-year period of 2003 through 2006.

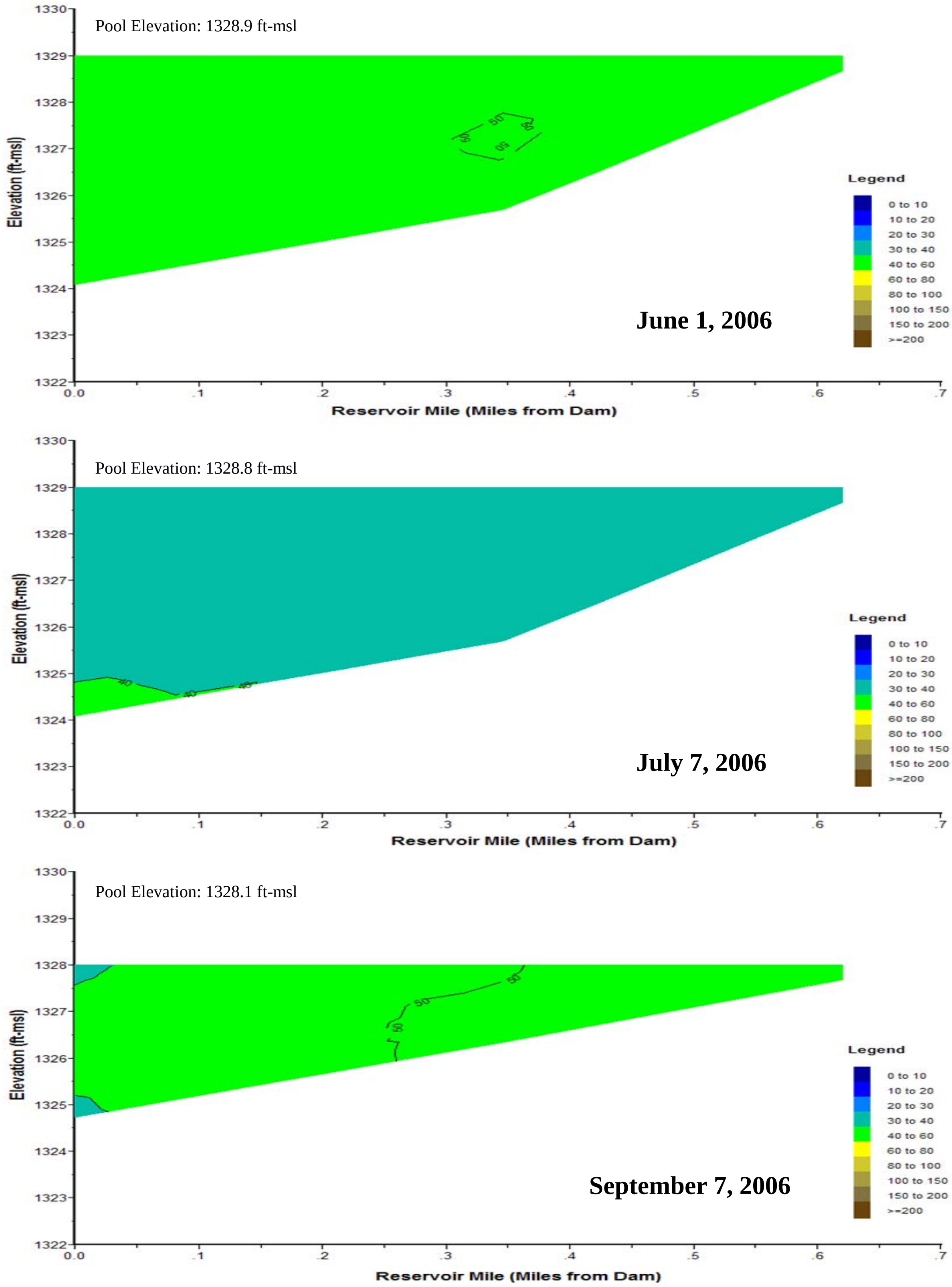

Plate 94. Longitudinal turbidity (NTU) contour plots of Olive Creek Reservoir based on depth-profile water temperatures measured at sites OCRLKND1 and OCRLKML1 in June, July, and September 2006.

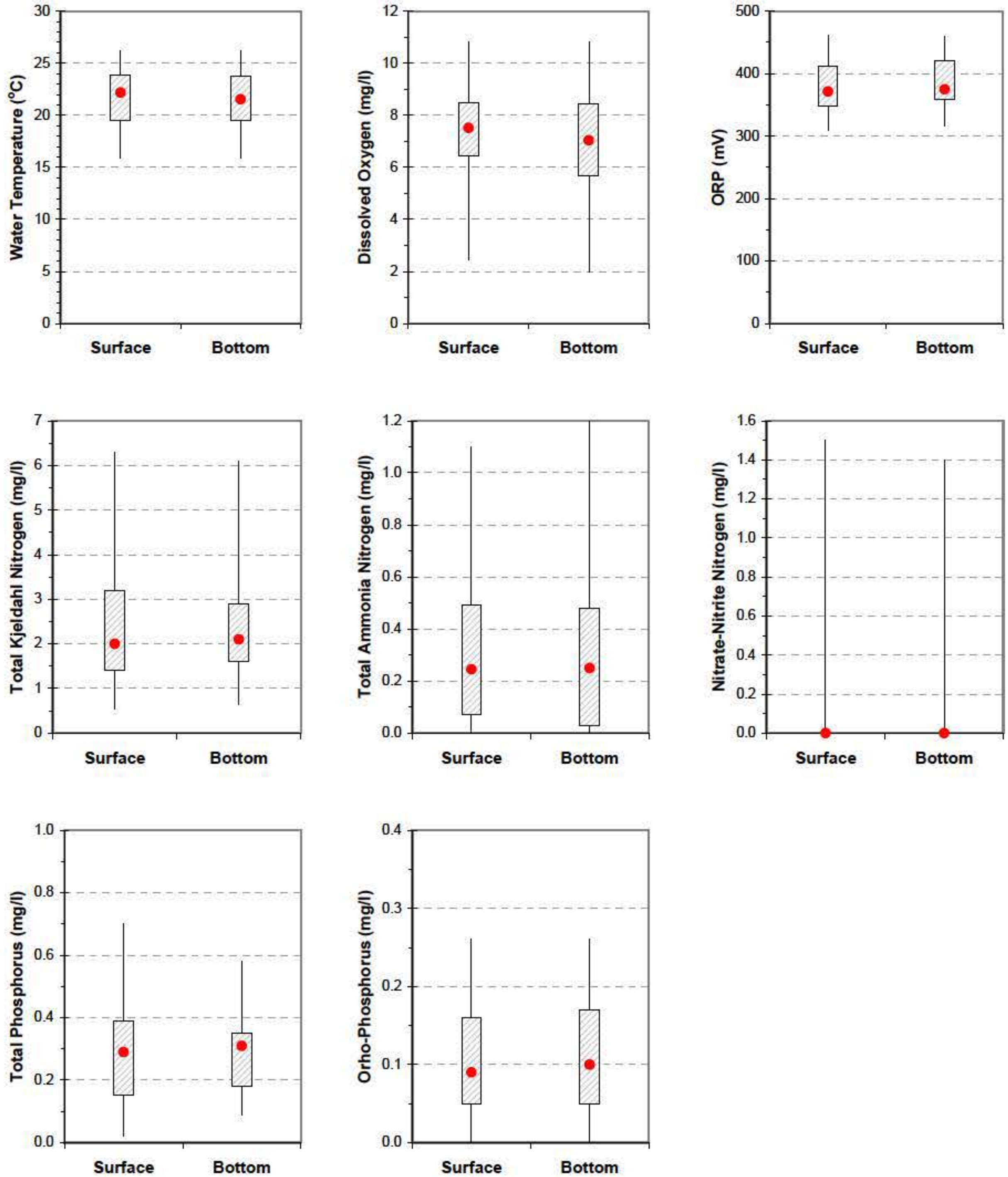

Plate 95. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Olive Creek Reservoir at site OCRLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

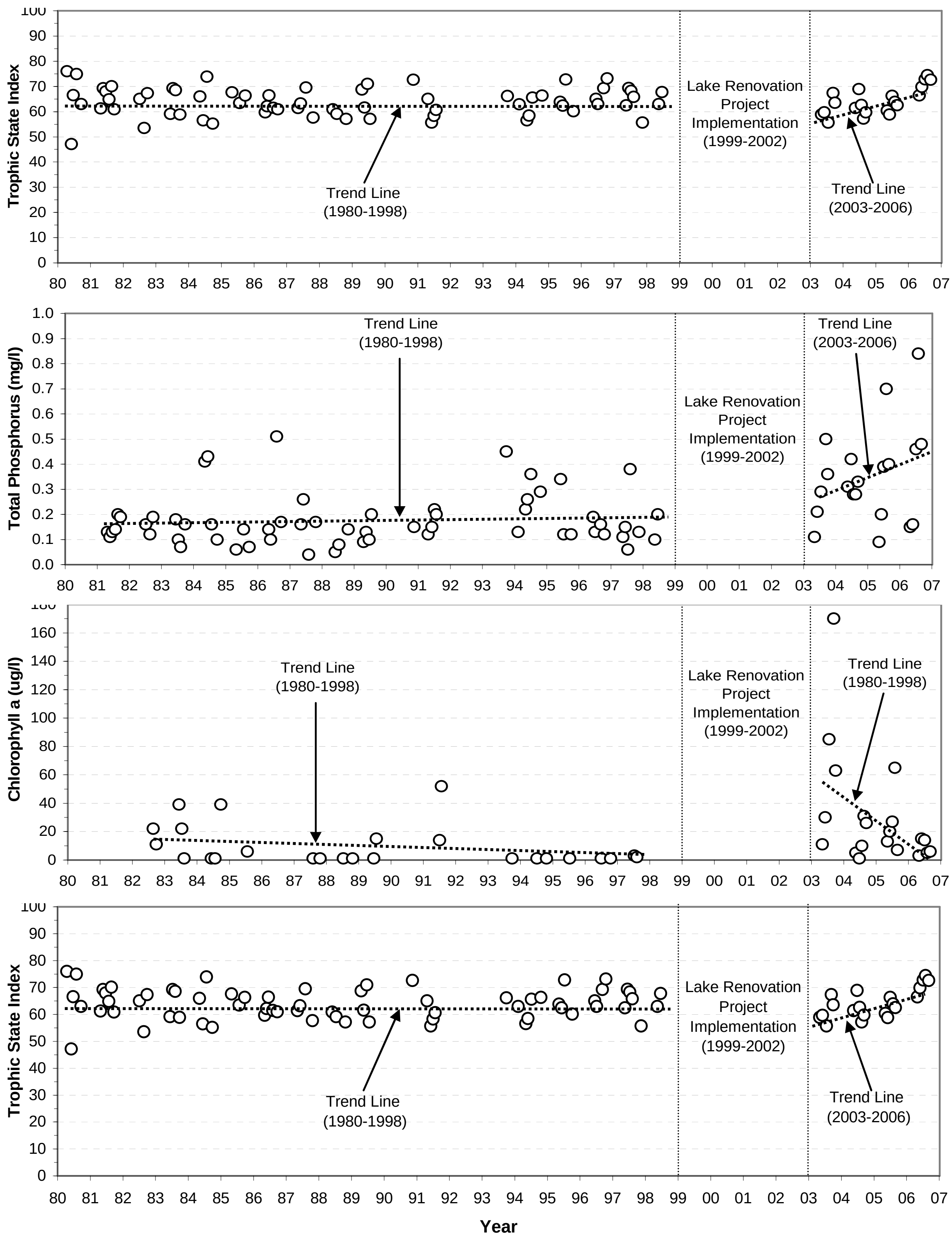

Plate 96. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Olive Creek Reservoir at the near-dam, ambient site (i.e., site OCRLKND1) over the 27-year period of 1980 to 2006. (Note: lake renovation project implemented from 2002 through 2005).

Plate 97. Summary of runoff water quality conditions monitored in the main west tributary inflow to Olive Creek Reservoir at monitoring site OCRNFWST1 during the period 2002 through 2006**.**

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Kjeldahl N, Total (mg/l)	0.1	5	4.5	4.4	2.5	6.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	5	13.38	11.80	0.77	26.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	5	1.26	1.26	0.63	1.82	-----	-----	-----
Suspended Solids, Total (mg/l)	4	5	810	680	364	1,630	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	5	0.50	0.49	0.19	0.90	760[(1)], 76[(2)]	0	0%
Atrazine, Total (ug/l)***	0.05	5	38.91	26.95	0.42	110.44	330[(1)], 12[(2)]	4	80%
Metolachlor, Total (ug/l)***	0.05	4	10.60	6.68	0.77	28.27	390[(1)], 100[(2)]	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** [(1)] Acute criterion for aquatic life.
[(2)] Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 98. Summary of runoff water quality conditions monitored in the main east tributary inflow to Olive Creek Reservoir at monitoring site OCRNFEST1 during the period 2002 through 2006**.**

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Kjeldahl N, Total (mg/l)	0.1	5	3.3	3.6	1.7	5.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	5	9.02	9.51	2.57	14.35	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	5	0.94	10.6	0.36	1.45	-----	-----	-----
Suspended Solids, Total (mg/l)	4	5	626	670	142	1,070	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	5	0.19	0.24	0.05	0.31	760[(1)], 76[(2)]	0	0%
Atrazine, Total (ug/l)***	0.05	5	28.93	17.16	0.30	102.01	330[(1)], 12[(2)]	3	60%
Metolachlor, Total (ug/l)***	0.05	5	1.98	2.65	0.25	3.88	390[(1)], 100[(2)]	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** [(1)] Acute criterion for aquatic life.
[(2)] Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 99. Summary of water quality conditions monitored in Pawnee Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site PAWLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1243.4	1243.4	1241.6	1244.5	-----	-----	-----
Water Temperature (C)	0.1	294	21.8	22.5	14.7	28.4	32	0	0%
Dissolved Oxygen (mg/l)	0.1	294	7.1	7.2	0.2	13.0	≥ 5.0	49	17%
Dissolved Oxygen (% Sat.)	0.1	283	82.5	85.5	2.0	155.7	-----	-----	-----
Specific Conductance (umho/cm)	1	283	361	368	303	433	-----	-----	-----
pH (S.U.)	0.1	283	8.5	8.4	7.3	9.4	≥6.5 & ≤9.0	10	4%
Turbidity (NTUs)	0.1	171	17.4	9.8	2.1	247.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	189	371	366	190	490	-----	-----	-----
Secchi Depth (in.)	1	24	41	32	12	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	170	177	103	200	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	0.35	0.31	n.d.	1.30	3.88 [1,2], 0.77 [1,3]	4	11%
Chlorophyll *a* (ug/l) – Field Probe	1	71	3	1	n.d.	37	16[5]	3	4%
Chlorophyll *a* (ug/l) – Lab Determined	1	23	24	11	2	100	16[5]	10	43%
Hardness, Total (mg/l)	0.4	17	150	146	123	195	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	1.3	1.3	0.2	2.4	-----	-----	-----
Nitrogen, Total (mg/)	0.1	48	1.3	1.3	0.2	2.5	1.54[5]	19	40%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.19	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.19	0.12	0.02	1.40	0.143[5]	18	36%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	-----	0.03	n.d.	0.42	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	12	11	n.d.	58	-----	-----	-----
Antimony, Dissolved (ug/l)	6	4	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	5	12	10	n.d.	25	340[2], 16.7[3,4]	0, 1	0%, 20%
Beryllium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	8.5[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	807[2], 105[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	3	19.2[2], 12.4[3]	0	0%
Lead, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	97[2], 3.8[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	5	-----	n.d.	n.d.	n.d.	645[2], 72[3]	0	0%
Selenium, Total (ug/l)	2	5	-----	n.d.	n.d.	5.1	20[2], 5[3]	0,1	0%, 20%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	6.6[2]	0	0%
Thallium (ug/l)	6	4	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	4.	163[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	0.5	n.d.	5.1	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	22	0.30	0.26	0.07	1.38	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	22	2.36	2.07	1.20	5.36	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	22	0.16	0.13	n.d.	0.51	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	5					*****	0	0%
Atrazine			-----	0.76	n.d.	2.40			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.5 and 22.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 146 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 100. Summary of water quality conditions monitored in Pawnee Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site PAWLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	23	1243.4	1243.4	1241.6	1244.5	-----	-----	-----
Water Temperature (C)	0.1	194	22.0	22.5	15.0	29.9	32	0	0%
Dissolved Oxygen (mg/l)	0.1	194	7.8	8.0	0 5	12.5	≥ 5.0	18	9%
Dissolved Oxygen (% Sat.)	0.1	184	92.6	92.8	6.8	149.6	-----	-----	-----
Specific Conductance (umho/cm)	1	184	357	367	118	403	-----	-----	-----
pH (S.U.)	0.1	184	8.6	8.6	7.6	9.4	≥6.5 & ≤9.0	15	8%
Turbidity (NTUs)	0.1	110	27.8	20.8	3.8	86.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	127	368	357	206	498	-----	-----	-----
Secchi Depth (in.)	1	23	26	20	9	90	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	42	5	5	n.d.	19	16(5)	2	5%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

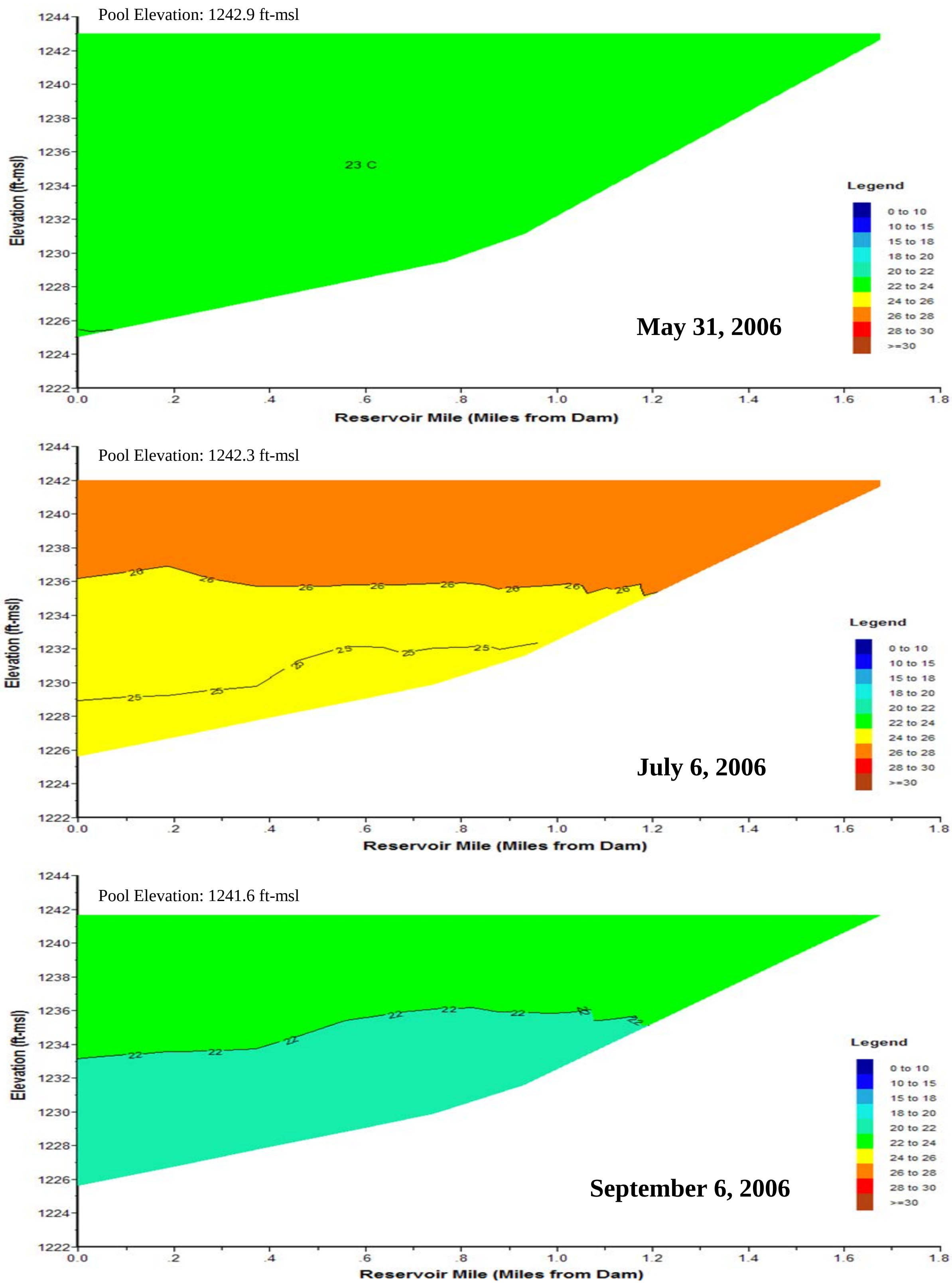

Plate 101. Longitudinal water temperature (°C) contour plots of Pawnee Reservoir based on depth-profile water temperatures measured at sites PAWLKND1 and PAWLKML1 in May, July, and September 2006.

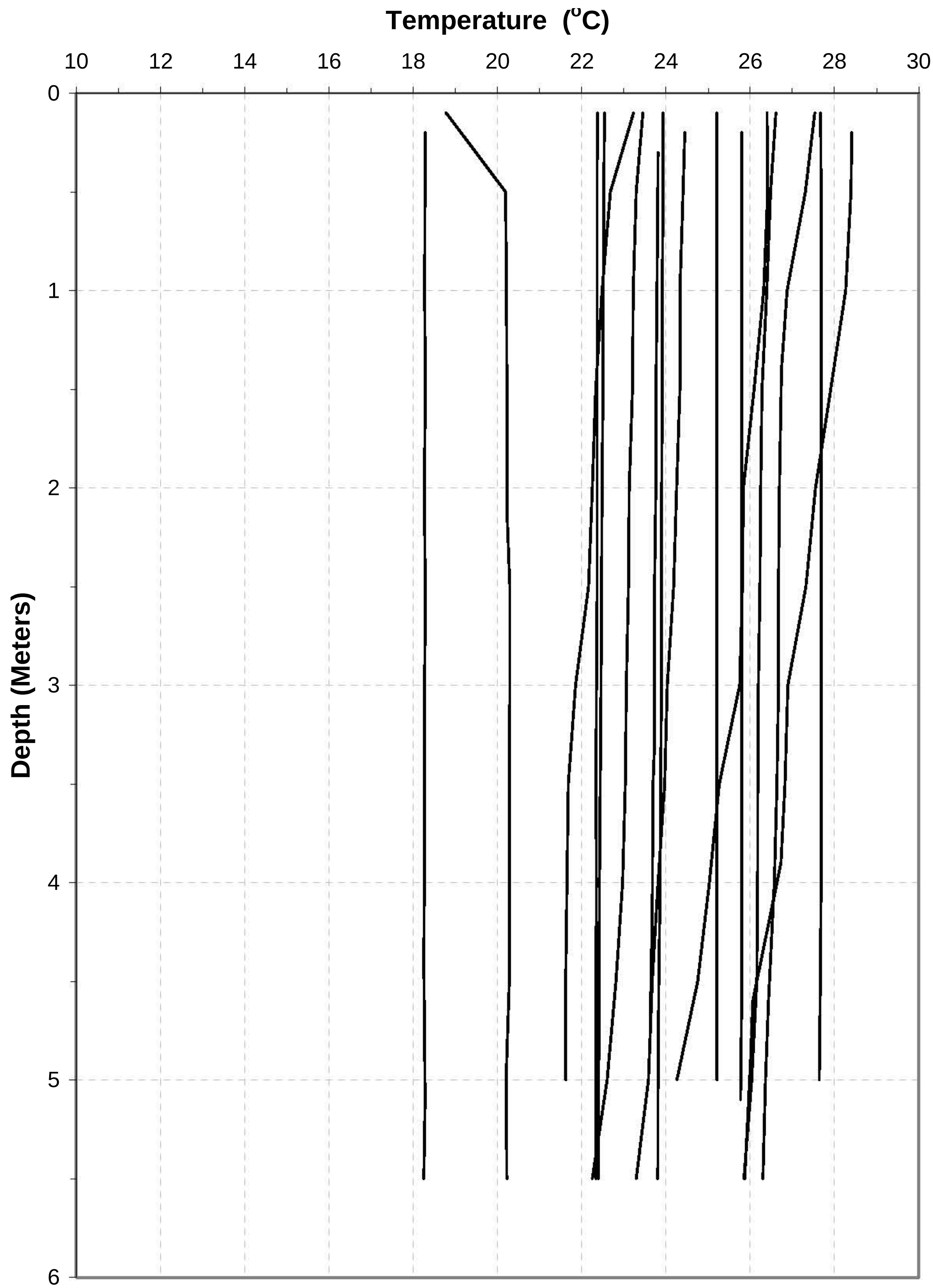

Plate 102. Temperature depth profiles for Pawnee Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., PAWLKND1) during the summer over the 5-year period of 2002 through 2006.

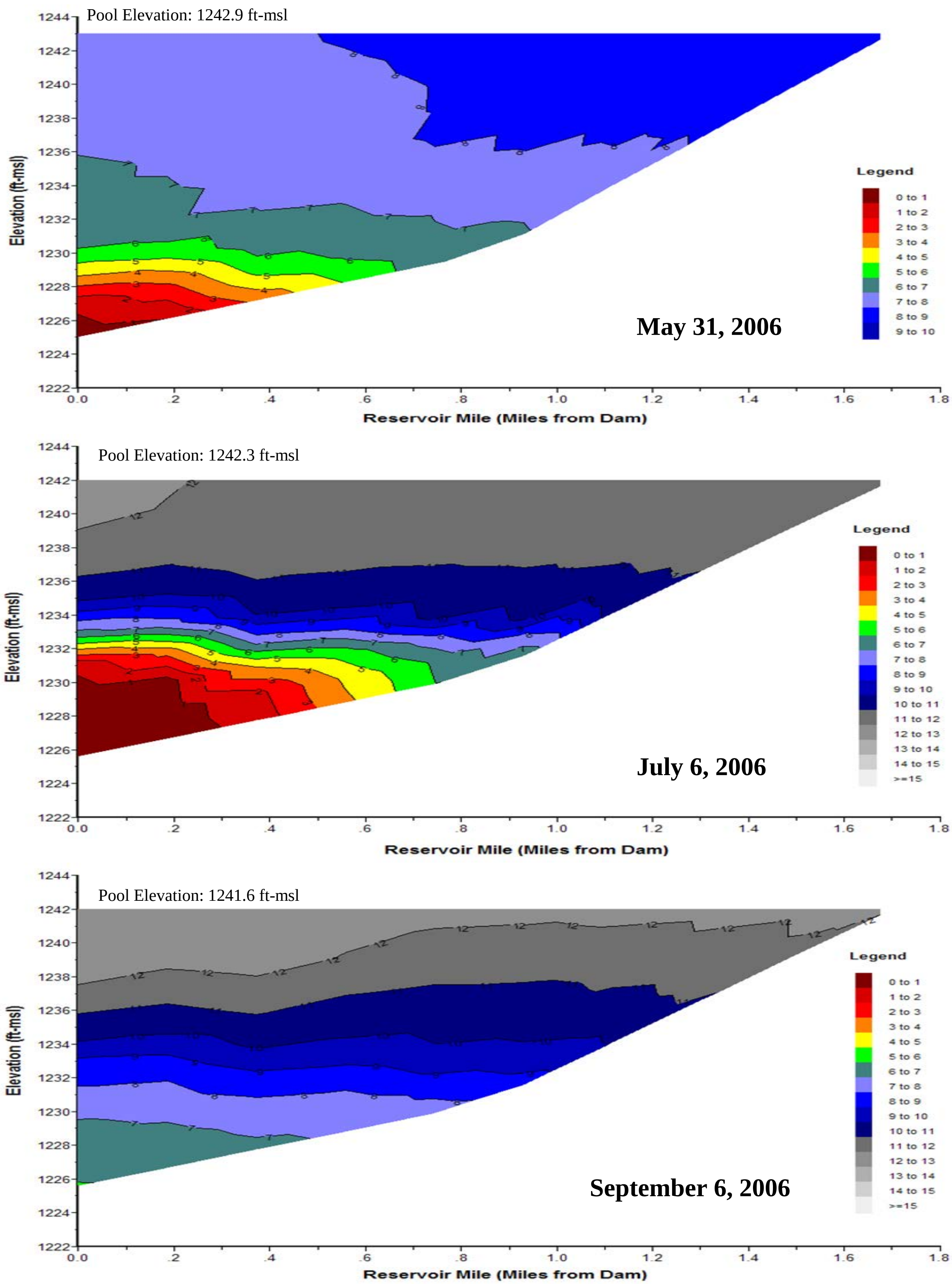

Plate 103. Longitudinal dissolved oxygen (mg/l) contour plots of Pawnee Reservoir based on depth-profile dissolved oxygen concentrations measured at sites PAWLKND1 and PAWLKML1 in May, July, and September 2006.

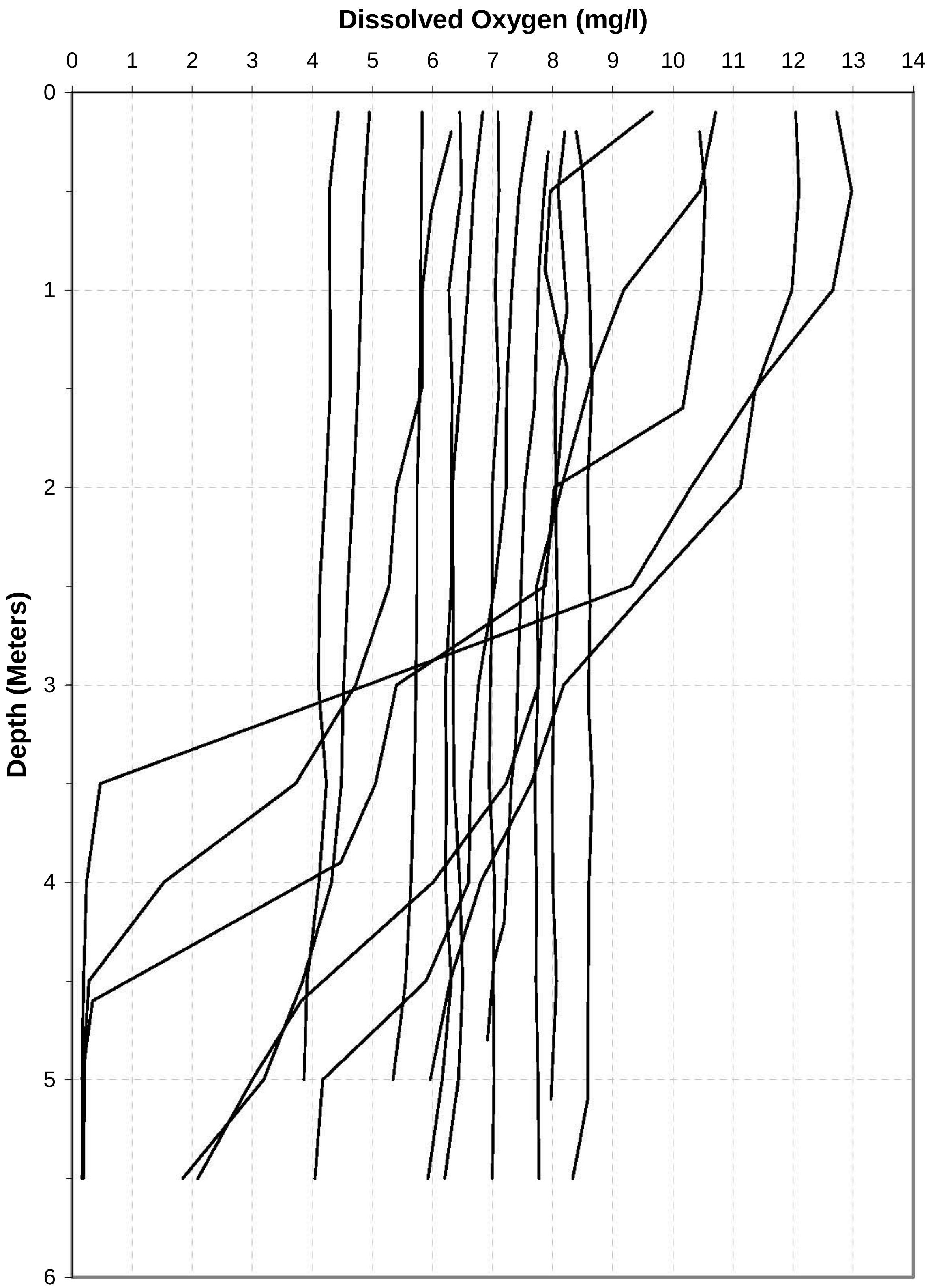

Plate 104. Dissolved oxygen depth profiles for Pawnee Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., PAWLKND1) during the summer of the 5-year period of 2002 through 2006.

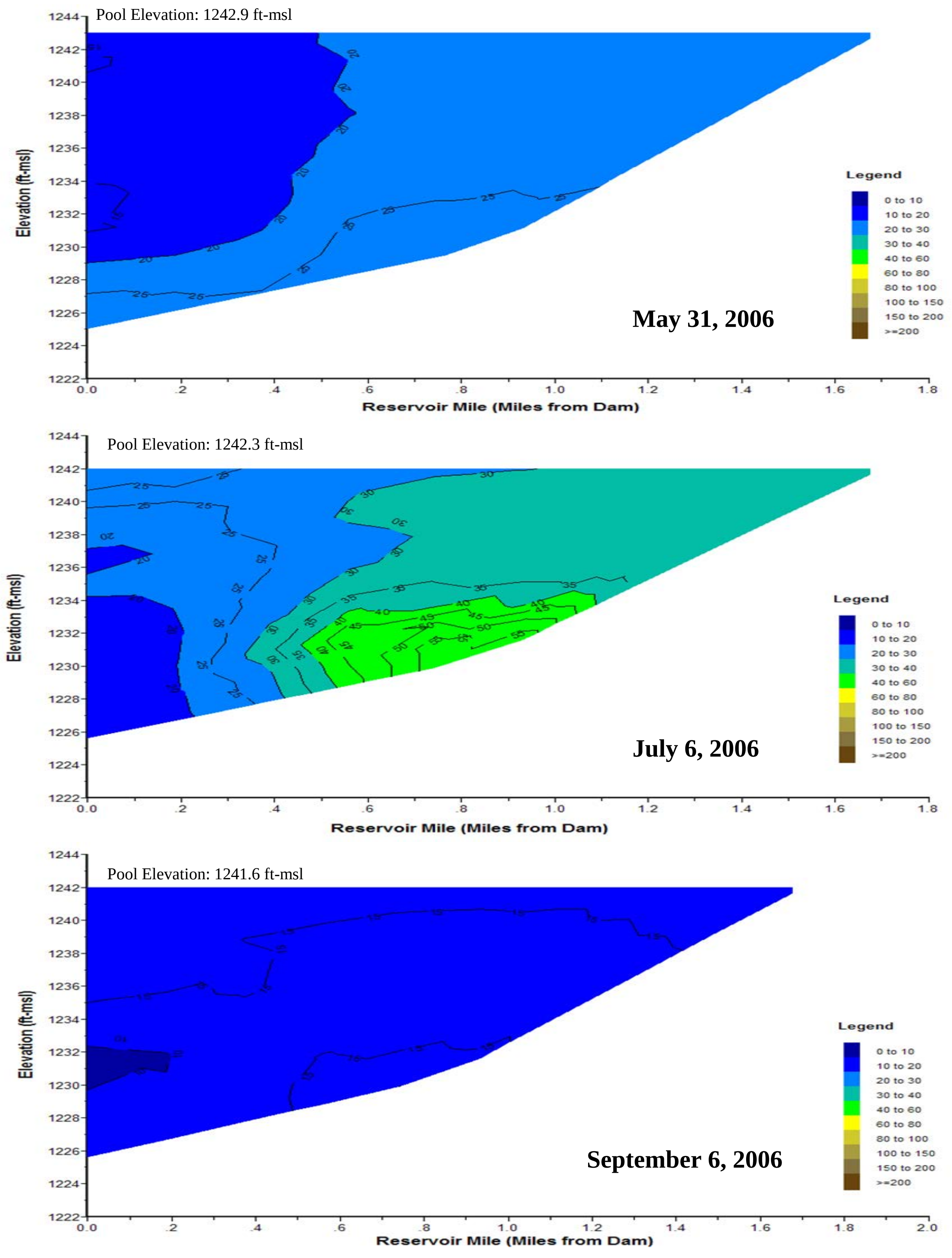

Plate 105. Longitudinal turbidity (NTU) contour plots of Pawnee Reservoir based on depth-profile turbidity levels measured at sites PAWLKND1 and PAWLKML1 in May, July, and September 2006.

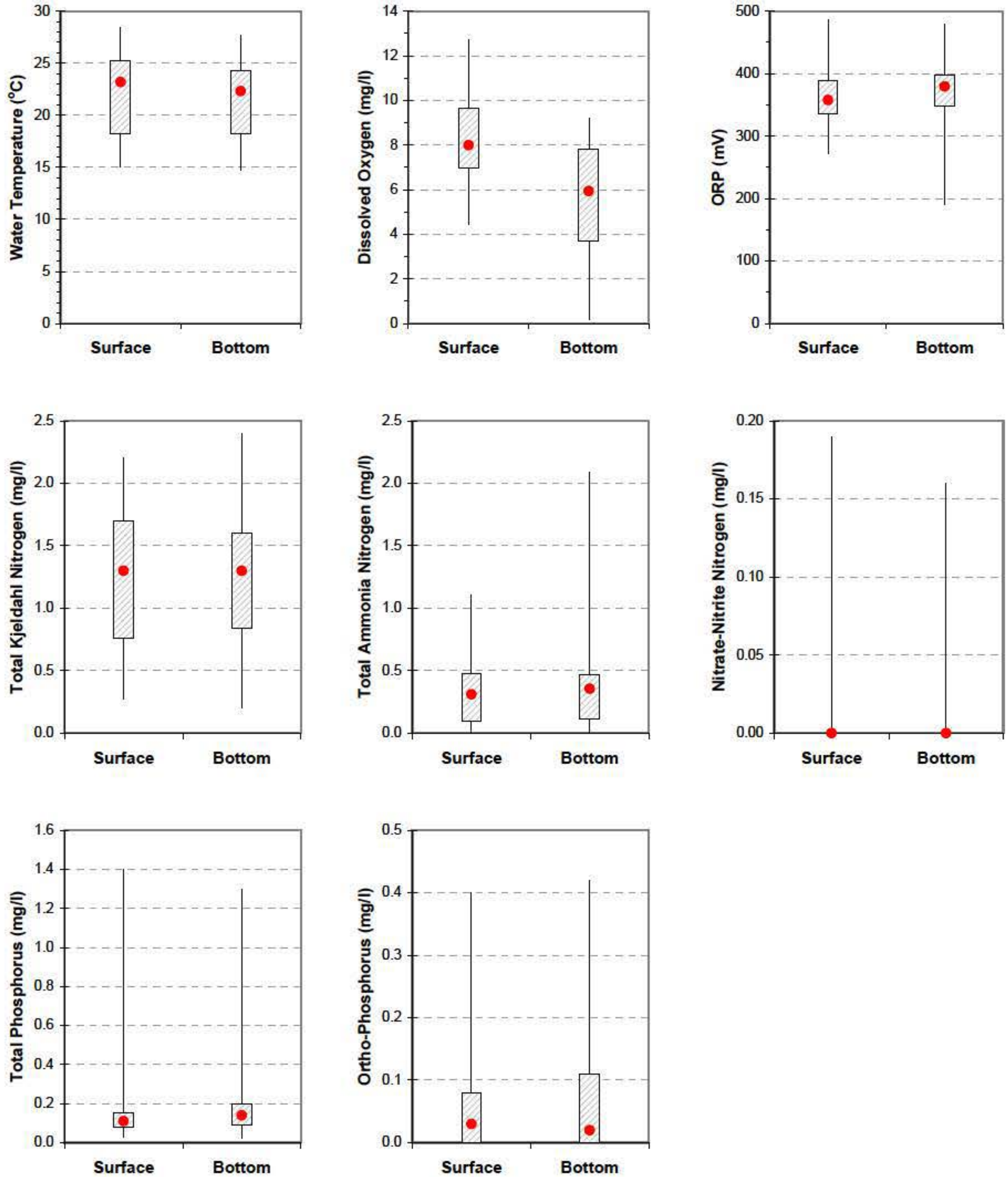

Plate 106. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Pawnee Reservoir at site PAWLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

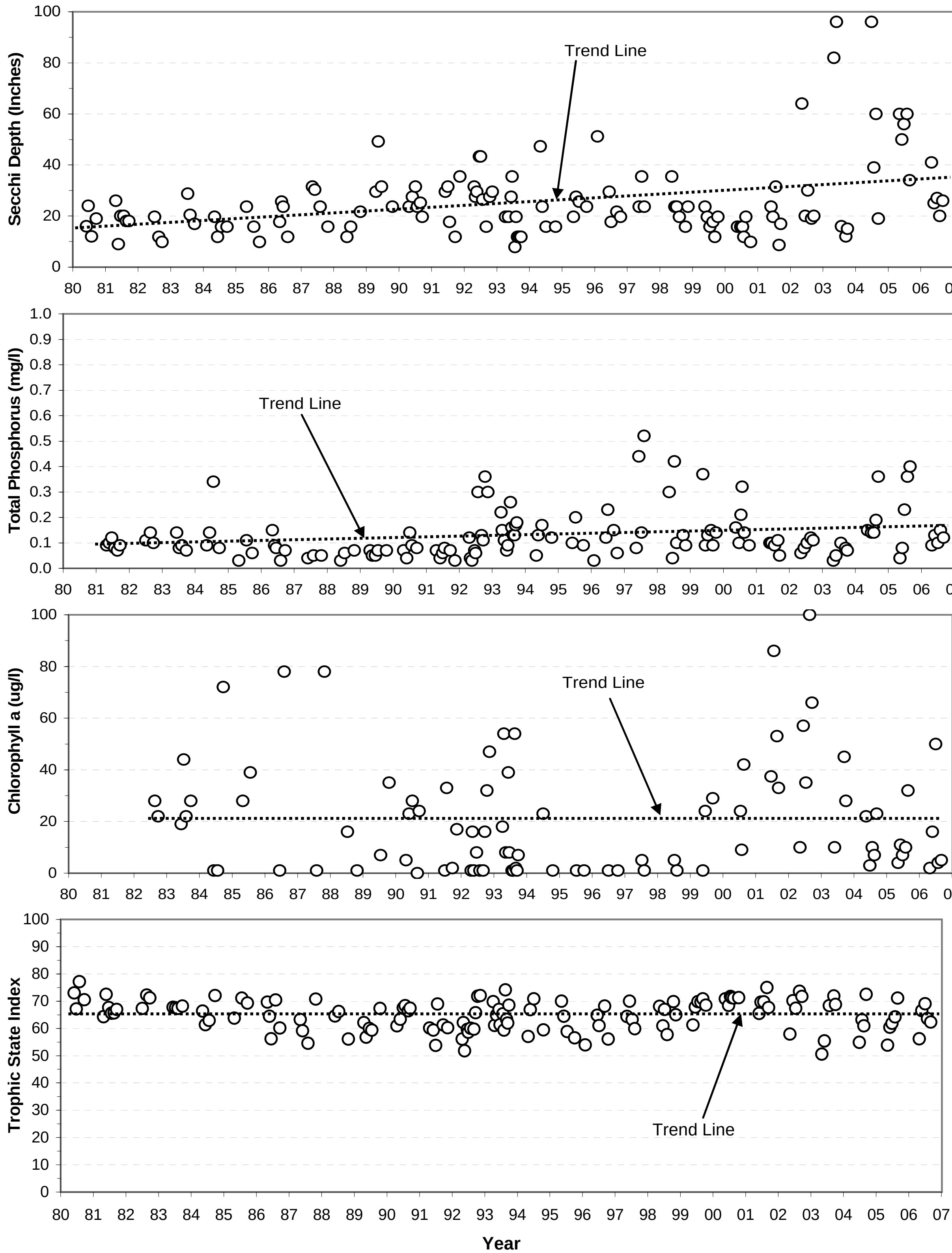

Plate 107. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Pawnee Reservoir at the near-dam, ambient site (i.e., site PAWLKND1) over the 27-year period of 1980 to 2006.

Plate 108. Summary of runoff water quality conditions monitored in the main tributary inflow to Pawnee Reservoir at monitoring site PAWNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	9	4.2	4.1	1.4	7.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	1.40	1.30	n.d.	2.61	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	9	1.44	1.53	0.57	2.30	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	940	1,030	48	2,050	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	9	1.03	0.52	0.10	3.20	$760^{(1)}$, $76^{(2)}$	0	0%
Atrazine, Total (ug/l)***	0.05	9	13.45	12.10	0.35	43.45	$330^{(1)}$, $12^{(2)}$	5	56%
Metolachlor, Total (ug/l)***	0.05	9	4.62	2.42	0.16	25.30	$390^{(1)}$, $100^{(2)}$	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.

** $^{(1)}$ Acute criterion for aquatic life.

$^{(2)}$ Chronic criterion for aquatic life.

*** Immunoassay analysis.

Plate 109. Summary of water quality conditions monitored in Stagecoach Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site STGLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1270.9	1270.9	1270.0	1273.3	-----	-----	-----
Water Temperature (C)	0.1	191	22.7	23.2	15.3	30.0	32	0	0%
Dissolved Oxygen (mg/l)	0.1	191	6.5	6.7	0.2	13.0	≥ 5.0	48	25%
Dissolved Oxygen (% Sat.)	0.1	184	76.6	79.8	2.5	177.3	-----	-----	-----
Specific Conductance (umho/cm)	1	191	368	369	214	488	-----	-----	-----
pH (S.U.)	0.1	191	8.2	8.2	7.1	9.2	≥6.5 & ≤9.0	6	3%
Turbidity (NTUs)	0.1	124	123.0	24.9	7.3	1,000	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	133	377	382	286	483	-----	-----	-----
Secchi Depth (in.)	1	24	16	16	2	38	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	154	156	50	210	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	-----	0.13	n.d.	0.92	5.72 [1,2], 1.02 [1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	46	61	50	31	122	16[5]	46	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	23	28	14	n.d.	131	16[5]	9	39%
Hardness, Total (mg/l)	0.4	16	171	164	132	214	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	1.1	1.1	n.d.	2.2	-----	-----	-----
Nitrogen, Total (mg/)	0.1	48	1.3	1.2	n.d.	3.6	1.54[5]	11	23%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	1.80	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.25	0.20	0.07	0.71	0.143[5]	33	66%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	0.09	0.07	n.d.	0.32	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	38	21	n.d.	370	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	4	n.d.	11	340[2], 16.7[3,4]	0	0%,
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	9.5[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	888[2], 116[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	21.4[2], 13.7[3]	0	0%
Lead, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	5	110[2], 4.3[3]	0, 1	0%, 20%
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	712[2], 79[3]	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	8 1[2]	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	6.	178[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	9	-----	n.d.	n.d.	0.3	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	23	0.21	0.20	0.06	0.38	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	24	3.76	2.16	n.d.	21.00	330[2], 12[3]	0, 2	0%, 8%
Metolachlor, Total (ug/l)***	0.05	23	0.76	0.58	n.d.	2.46	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	5					*****	0	0%
Acetochlor			-----	n.d.	n.d.	0.60			
Alachlor			-----	n.d.	n.d.	0.20			
Atrazine			1.46	0.40	n.d.	5.80			
Metolachlor			-----	n.d.	n.d.	1.80			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 23.2 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 164 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 110. Summary of water quality conditions monitored in Stagecoach Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site STGLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1270.9	1270.9	1270.0	1273.3	-----	-----	-----
Water Temperature (C)	0.1	153	22.6	23.2	15.0	30.5	32	0	0%
Dissolved Oxygen (mg/l)	0.1	153	6.5	6.9	0 3	12.2	≥ 5.0	38	25%
Dissolved Oxygen (% Sat.)	0.1	148	76.3	80.2	3 2	167.6	-----	-----	-----
Specific Conductance (umho/cm)	1	153	367	373	213	486	-----	-----	-----
pH (S.U.)	0.1	153	8.1	8.2	7.0	9.1	≥6.5 & ≤9.0	7	5%
Turbidity (NTUs)	0.1	83	56.5	29.2	8.8	402.2	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	108	379	381	301	487	-----	-----	-----
Secchi Depth (in.)	1	24	16	14	2	45	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	38	60	47	31	107	16(5)	38	100%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

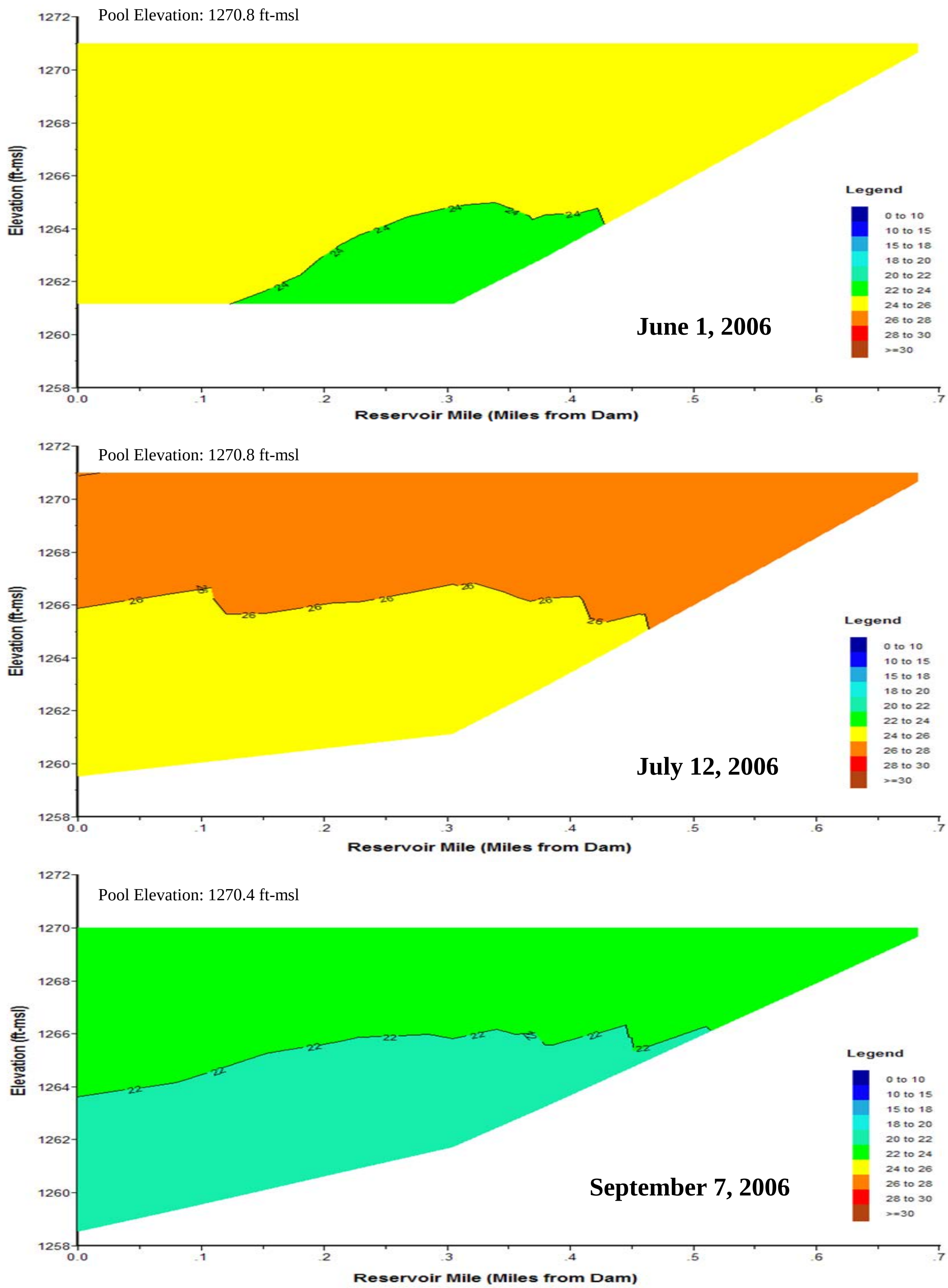

Plate 111. Longitudinal water temperature (°C) contour plots of Stagecoach Reservoir based on depth-profile water temperatures measured at sites STGLKND1 and STGLKML1 in June, July, and September 2006.

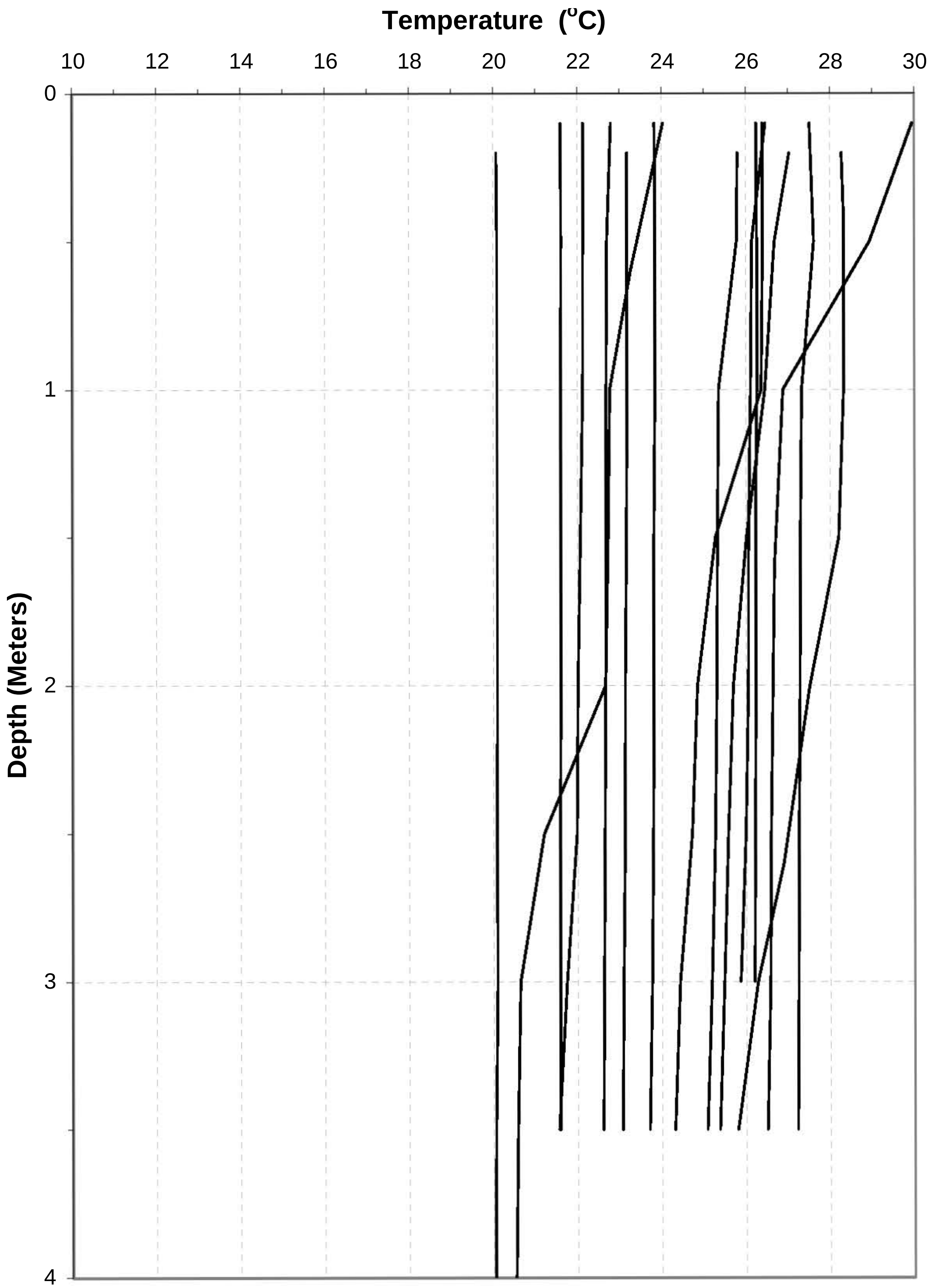

Plate 112. Temperature depth profiles for Stagecoach Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., STGLKND1) during the summer over the 5-year period of 2002 through 2006.

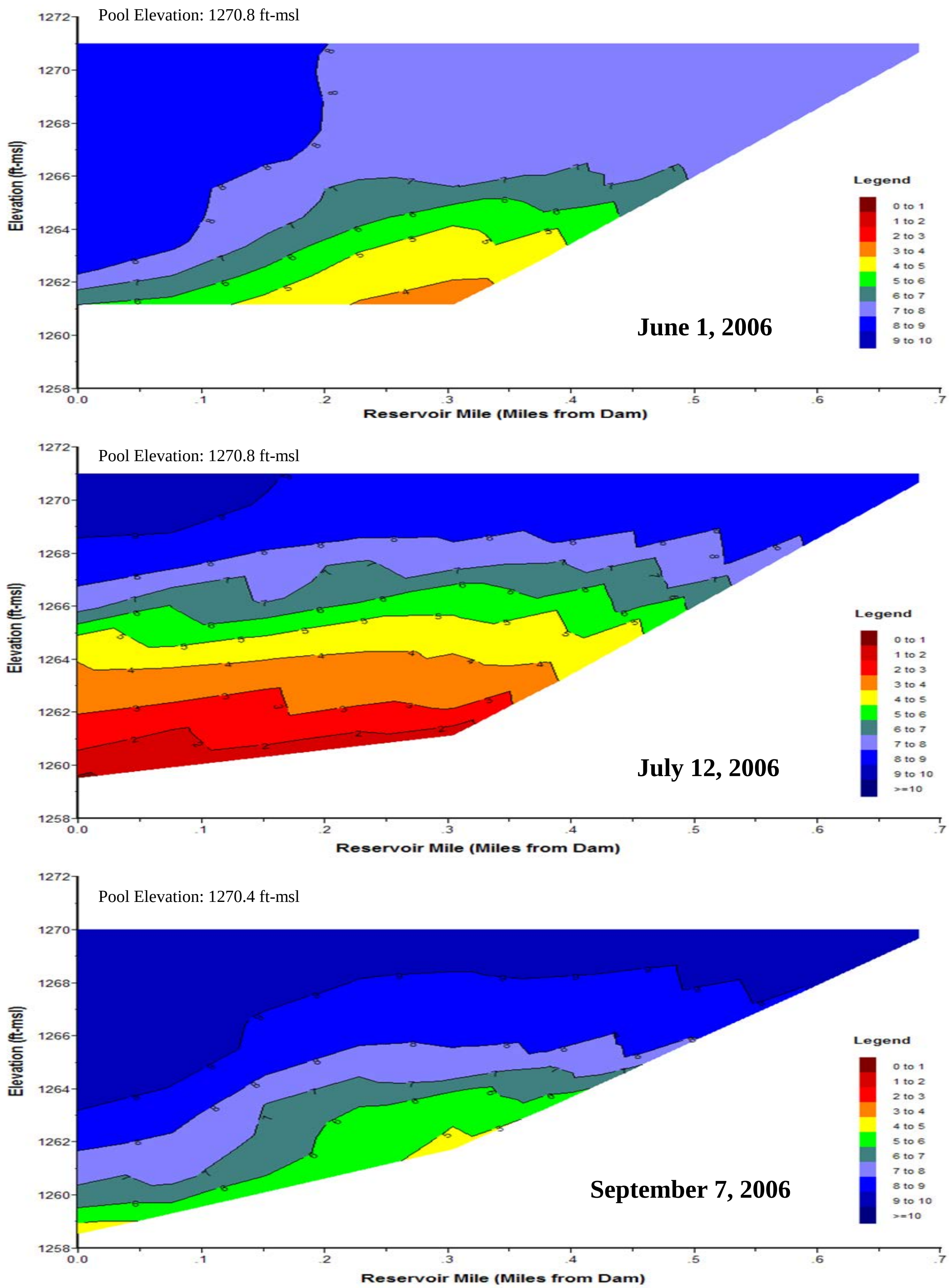

Plate 113. Longitudinal dissolved oxygen (mg/l) contour plots of Stagecoach Reservoir based on depth-profile dissolved oxygen concentrations measured at sites STGLKND1 and STGLKML1 in June, July, and September 2006.

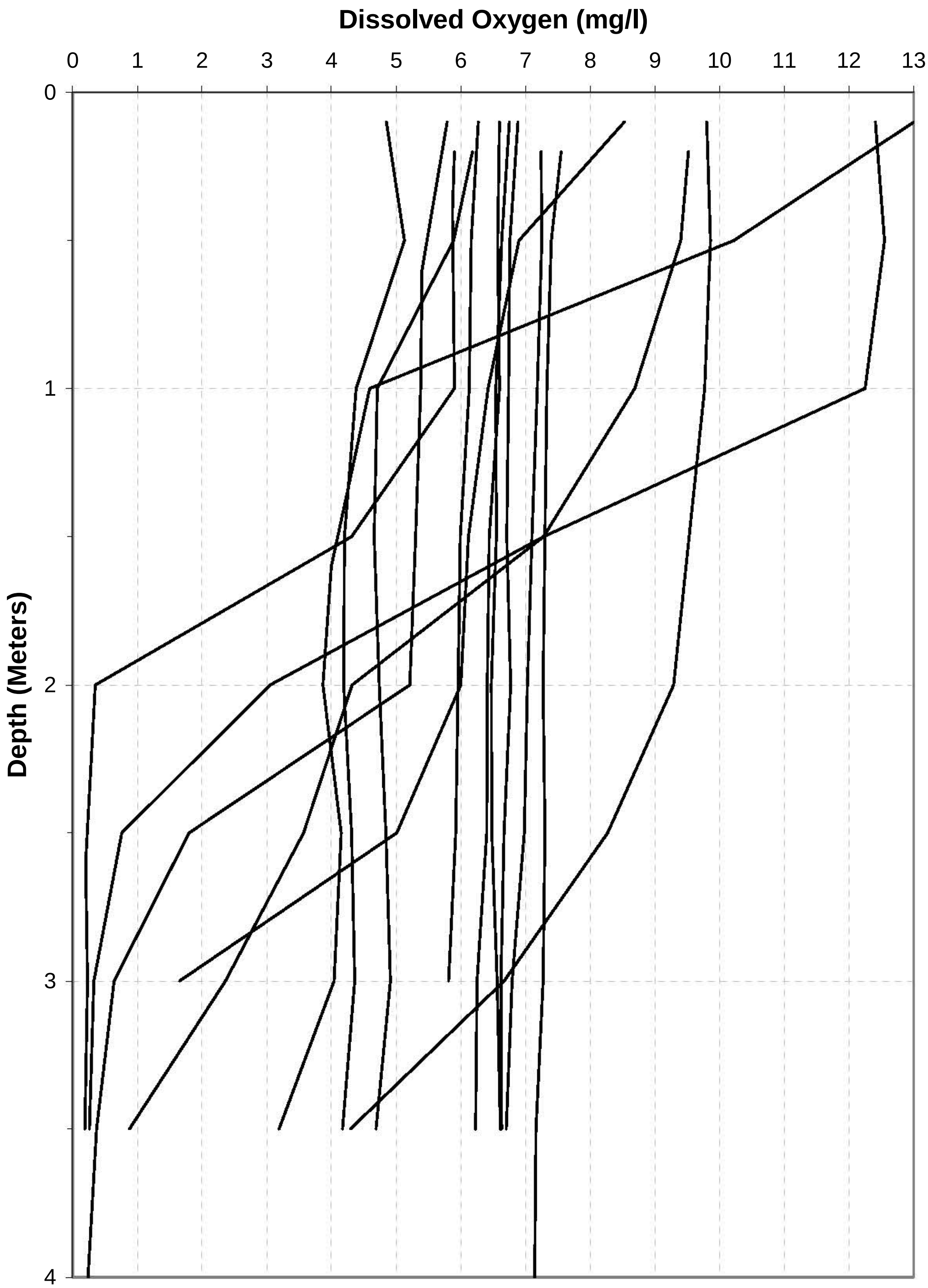

Plate 114. Dissolved oxygen depth profiles for Stagecoach Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., STGLKND1) during the summer over the 5-year period of 2002 through 2006.

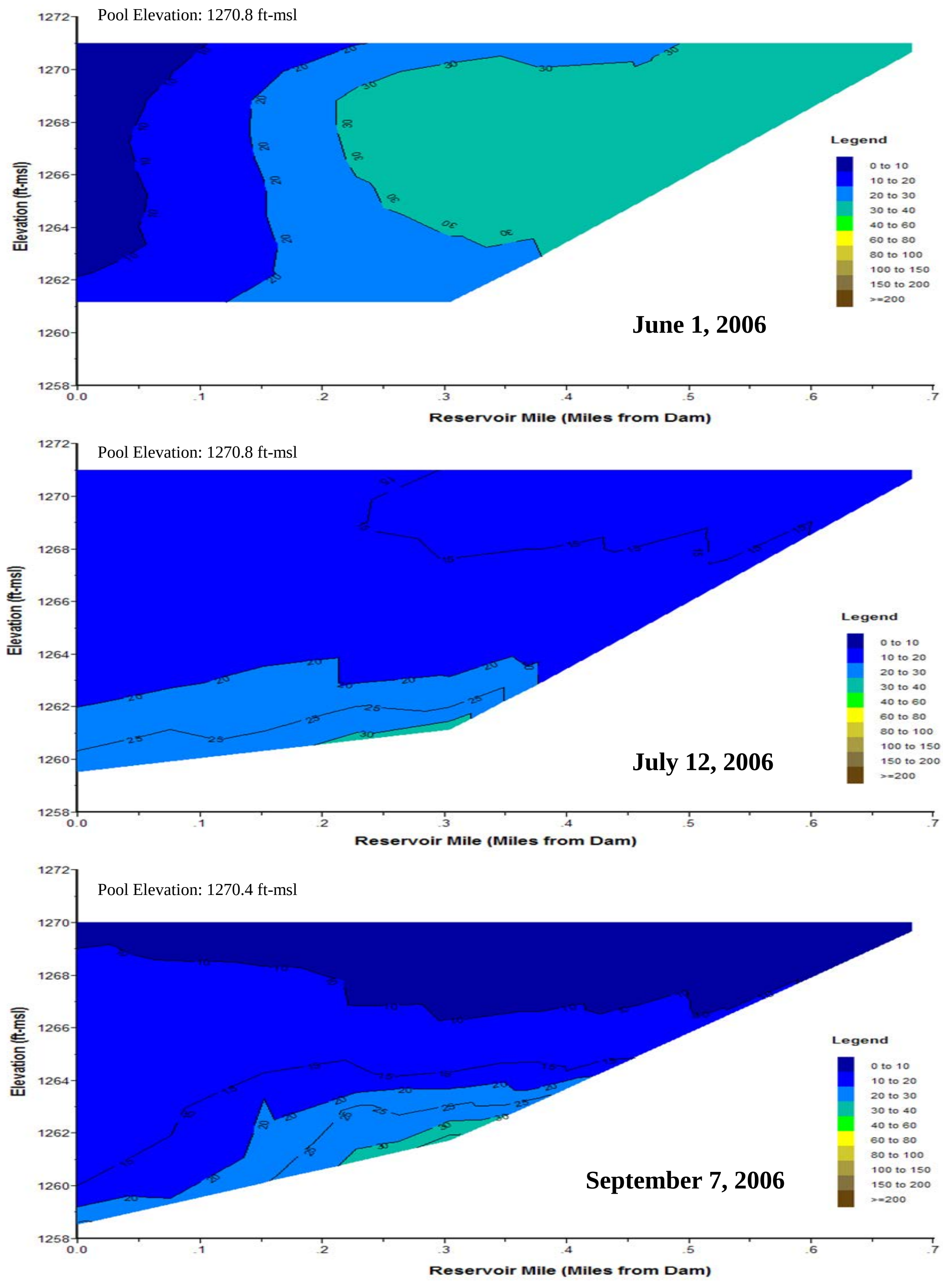

Plate 115. Turbidity (NTU) contour plots of Stagecoach Reservoir based on depth-profile turbidity levels measured at sites STGLKND1 and STGLKML1 in June, July, and September 2006.

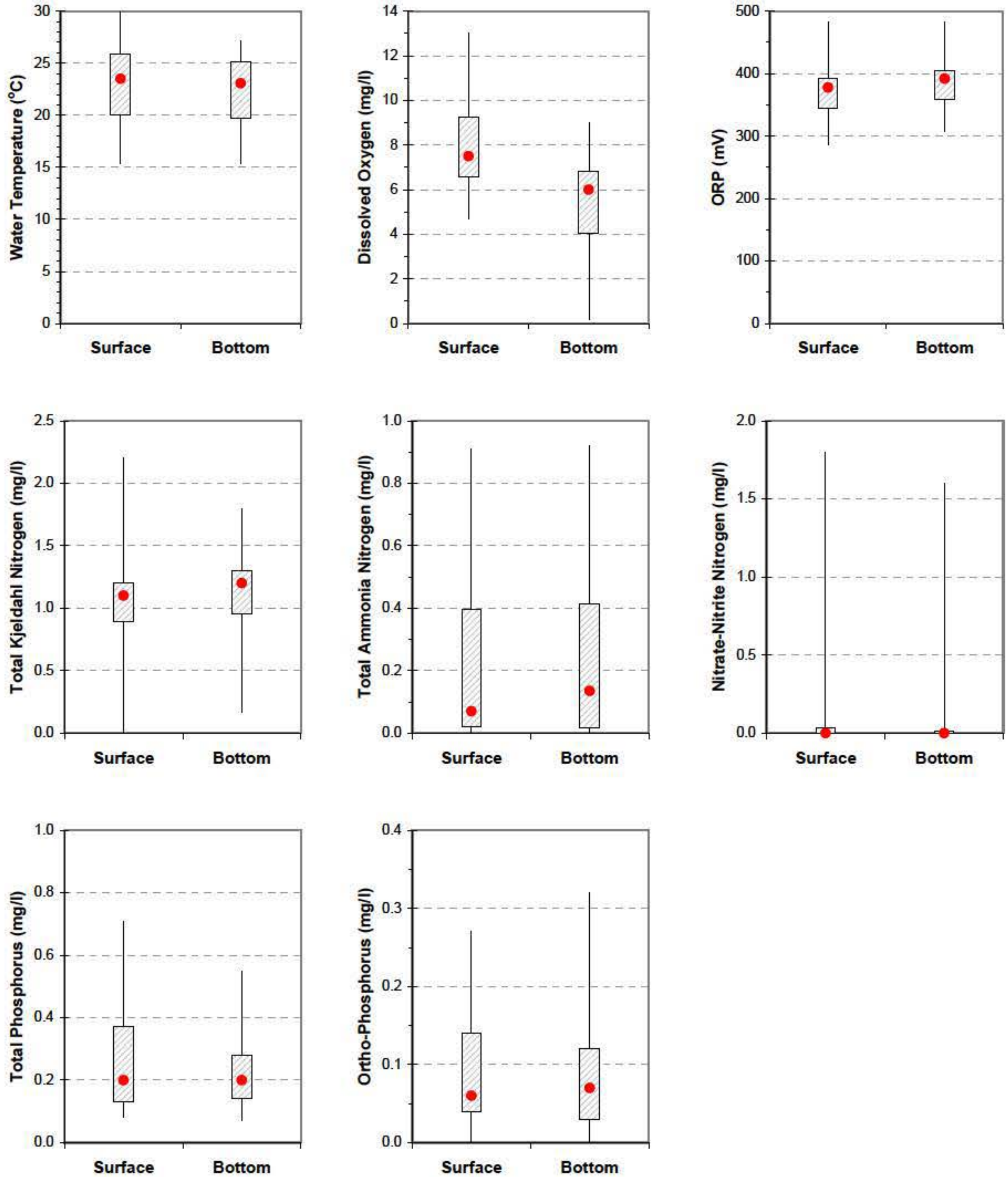

Plate 116. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Stagecoach Reservoir at site STGLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

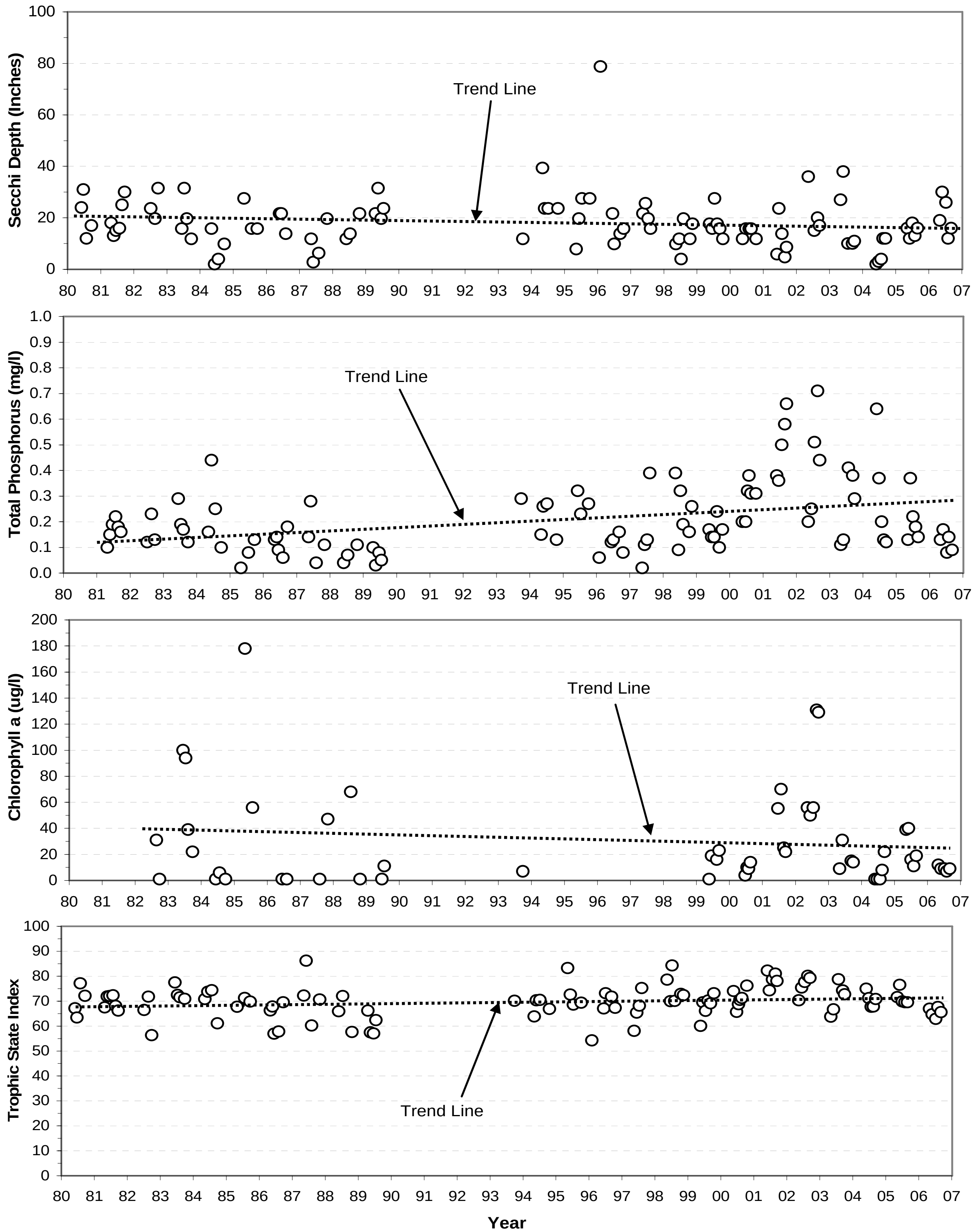

Plate 117. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Stagecoach Reservoir at the near-dam, ambient site (i.e., site STGLKND1) over the 27-year period of 1980 to 2006.

Plate 118. Summary of runoff water quality conditions monitored in the south tributary inflow to Stagecoach Reservoir at monitoring site STGNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	7	6.0	4.2	0.9	16.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	7	3.70	2.12	0.09	10.40	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	7	1.61	0.87	0.38	4.43	-----	-----	-----
Suspended Solids, Total (mg/l)	4	7	608	340	76	2,500	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	6	0.32	0.27	0.05	0.64	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	7	17.08	4.18	0.25	55.55	330(1), 12(2)	2	29%
Metolachlor, Total (ug/l)***	0.05	7	9.88	3.10	0.07	37.18	390(1), 100(2)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 119. Summary of water quality conditions monitored in East Twin Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site ETNLKND1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for “grab samples” collected at ½ the measured Secchi depth. Results for other parameters are for “grab samples” collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1339.5	1339.7	1336.7	1341.5	-----	-----	-----
Water Temperature (C)	0.1	264	22.2	23.4	14.6	28.7	32	0	0%
Dissolved Oxygen (mg/l)	0.1	264	6.7	7.1	0.1	17.1	≥ 5.0	37	14%
Dissolved Oxygen (% Sat.)	0.1	256	80.0	83.3	1.5	210.0	-----	-----	-----
Specific Conductance (umho/cm)	1	256	368	370	311	573	-----	-----	-----
pH (S.U.)	0.1	256	8.2	8.2	7.1	9.2	≥6.5 & ≤9.0	2	1%
Turbidity (NTUs)	0.1	148	28.1	22.7	8.0	120	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	158	356	356	84	482	-----	-----	-----
Secchi Depth (in.)	1	25	23	22	2	36	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	137	141	81	176	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	0.29	0.16	n.d.	1.10	5.72 [1,2], 1.01 [1,3]	0, 2	0%, 6%
Chlorophyll *a* (ug/l) – Field Probe	1	61	17	16	5	32	16[5]	30	49%
Chlorophyll *a* (ug/l) – Lab Determined	1	22	25	18	3	83	16[5]	12	55%
Hardness, Total (mg/l)	0.4	9	153	140	129	180	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	50	1.3	1.3	0.4	2.7	-----	-----	-----
Nitrogen, Total (mg/)	0.1	49	1.3	1.3	0.4	2.7	1.54[5]	18	37%
Nitrate-Nitrite N, Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.52	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.10	0.09	0.02	0.37	0.143[5]	6	12%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	16	14	4	75	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	4	340[2], 16.7[3,4]	0	0%,
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d,	8.2[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	780[2], 102[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	18.5[2], 11.9[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	93[2], 3.6[3]	0, 1	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	622[2], 69[3]	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	6 2[2]	0	0%
Thallium (ug/l)	6	3	-----	n.d.	n.d.	n.d.	1,400[2], 6.3[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	4	n.d.	8	156[2,3]	0	0%
Microcystins, Total (ug/l)	0.2	8	-----	n.d.	n.d.	0.2	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	22	1.11	0.92	0.31	1.85	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)***	0.05	22	2.60	2.58	1.58	5.23	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)***	0.05	22	0.72	0.44	n.d.	2.80	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)****	0.05	5					*****	0	0%
Acetochlor			-----	n.d.	n.d.	0.20			
Alachlor			-----	n.d.	n.d.	0.20			
Atrazine			1.78	1.10	1.00	3.40			
Metolachlor			-----	n.d.	n.d.	0.80			
Prometon			-----	n.d.	n.d.	0.10			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 23.4 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska’s WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 140 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don’t have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 120. Summary of water quality conditions monitored in East Twin Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site ETNLKML1) from May to September during the 5-year period 2002 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1339.5	1339.7	1336.7	1341.5	-----	-----	-----
Water Temperature (C)	0.1	191	22.3	23.5	14.8	28.5	32	0	0%
Dissolved Oxygen (mg/l)	0.1	190	7.5	7.3	0 3	14.6	≥ 5.0	13	7%
Dissolved Oxygen (% Sat.)	0.1	183	89.2	86.5	1.0	174.5	-----	-----	-----
Specific Conductance (umho/cm)	1	184	365	368	310	420	-----	-----	-----
pH (S.U.)	0.1	184	8.3	8.2	7 3	9.1	≥6.5 & ≤9.0	3	2%
Turbidity (NTUs)	0.1	104	26.4	24.2	12.8	60.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	120	371	365	244	487	-----	-----	-----
Secchi Depth (in.)	1	22	21	20	12	36	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	49	17	15	5	48	16(5)	23	47%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

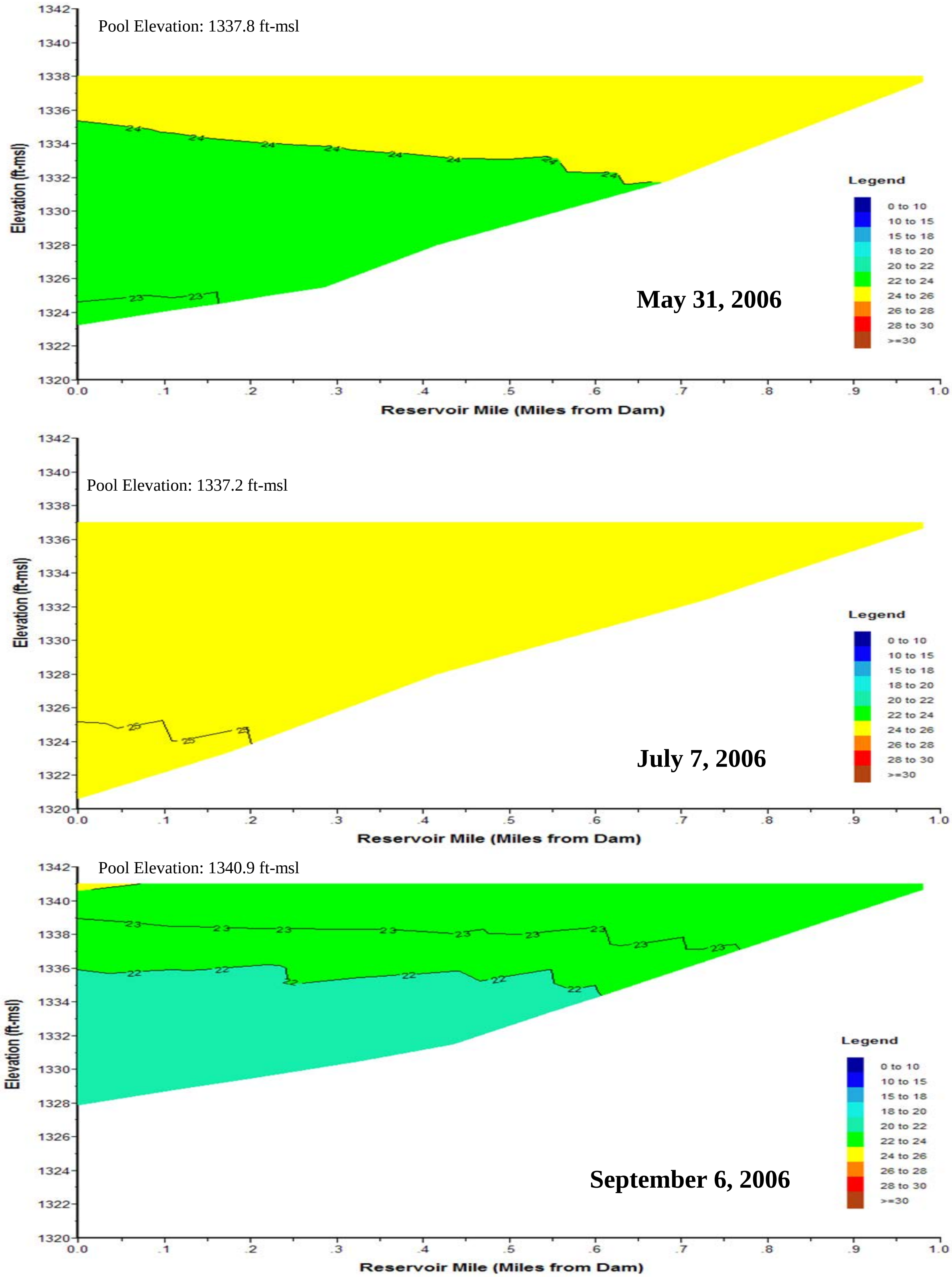

Plate 121. Longitudinal water temperature (°C) contour plots of East Twin Reservoir based on depth-profile water temperatures measured at sites ETNLKND1 and ETNLKML1 in May, July, and September 2006.

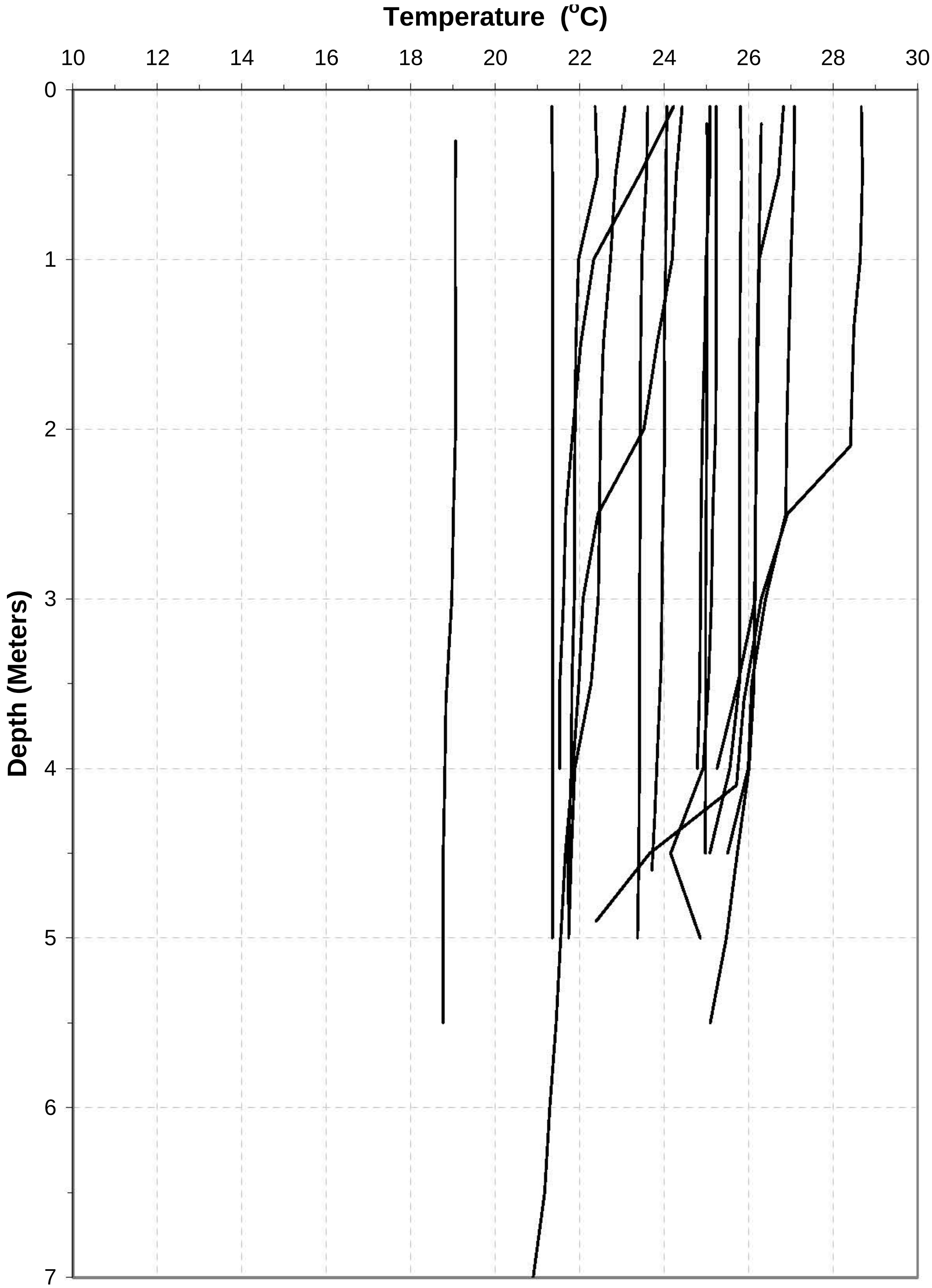

Plate 122. Temperature depth profiles for East Twin Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., ETNLKND1) during the summer over the 5-year period of 2002 through 2006.

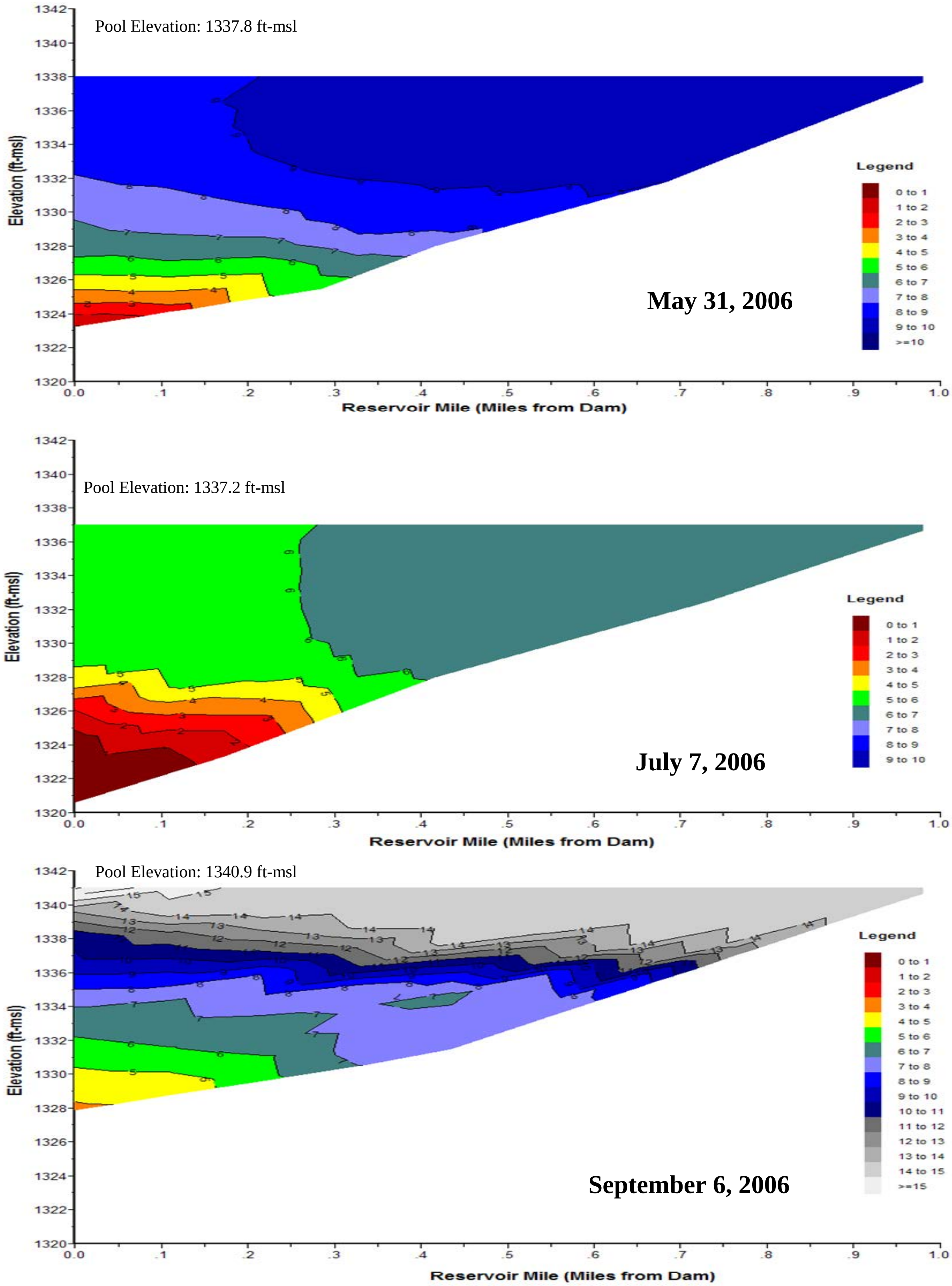

Plate 123. Longitudinal dissolved oxygen (mg/l) contour plots of East Twin Reservoir based on depth-profile dissolved oxygen concentrations measured at sites ETNLKND1 and ETNLKML1 in May, July, and September 2006.

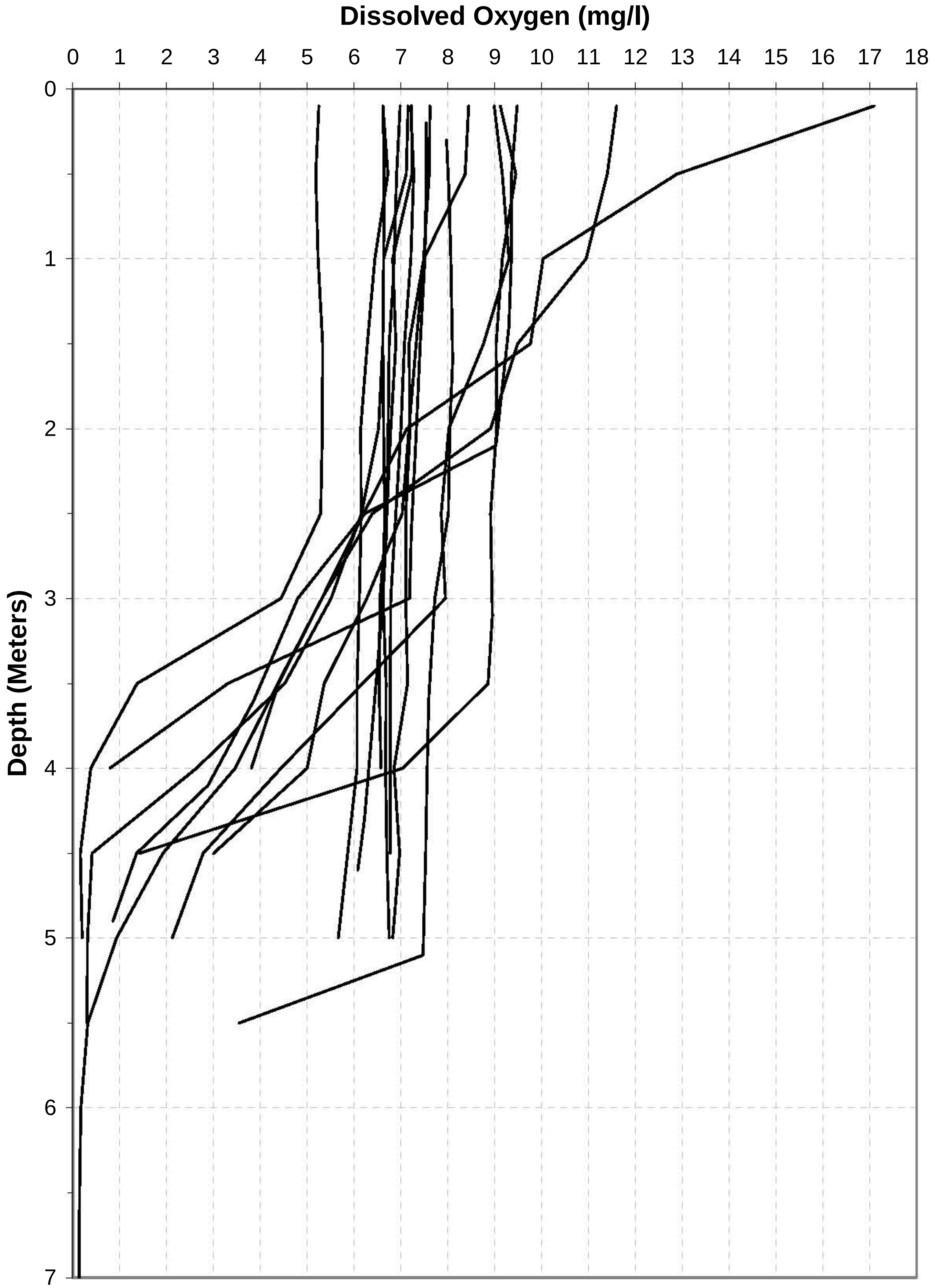

Plate 124. Dissolved oxygen depth profiles for East Twin Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., ETNLKND1) during the summer over the 5-year period of 2002 through 2006.

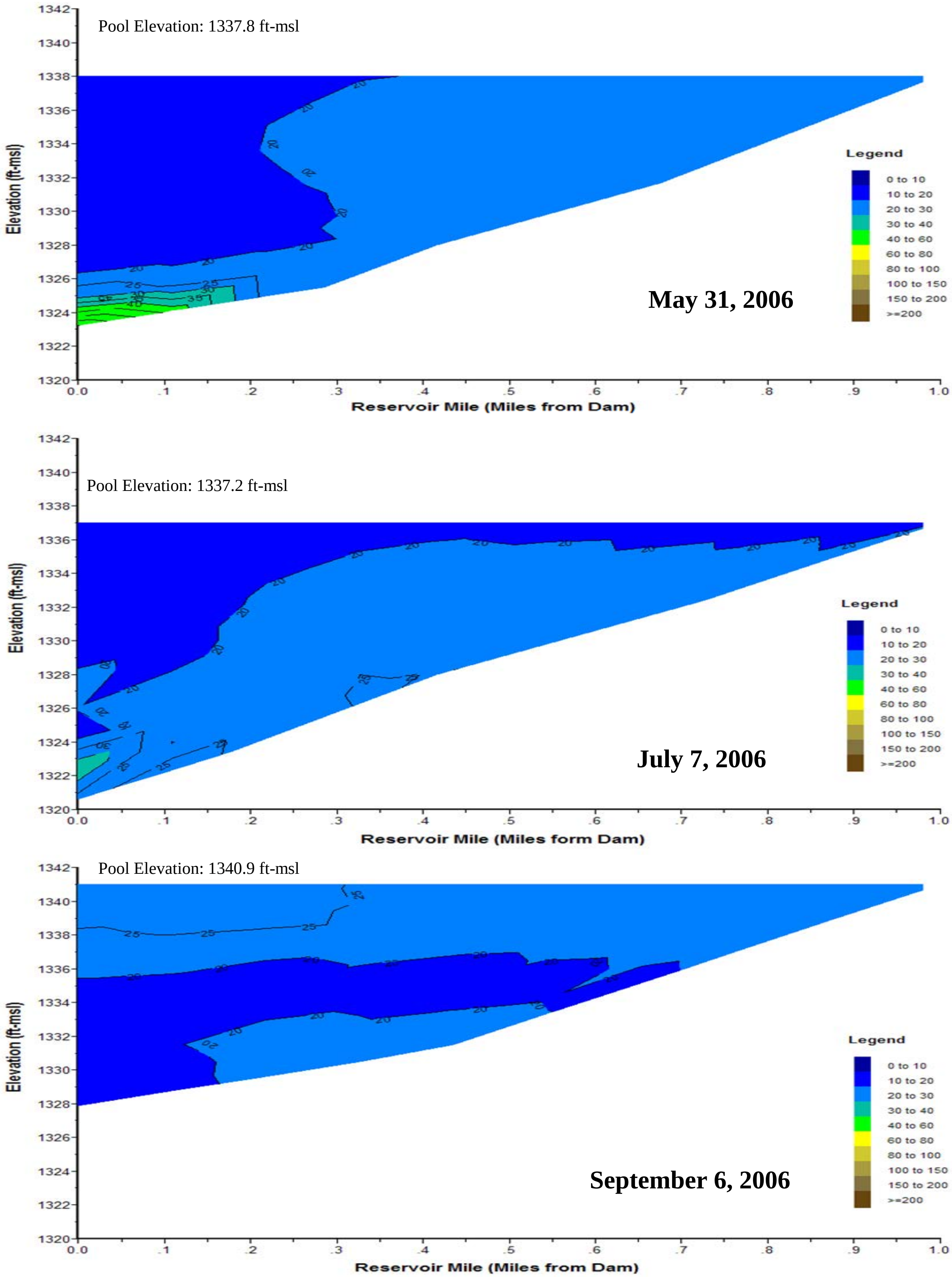

Plate 125. Longitudinal turbidity (NTU) contour plots of East Twin Reservoir based on depth-profile turbidity levels measured at sites ETNLKND1 and ETNLKML1 in May, July, and September 2006.

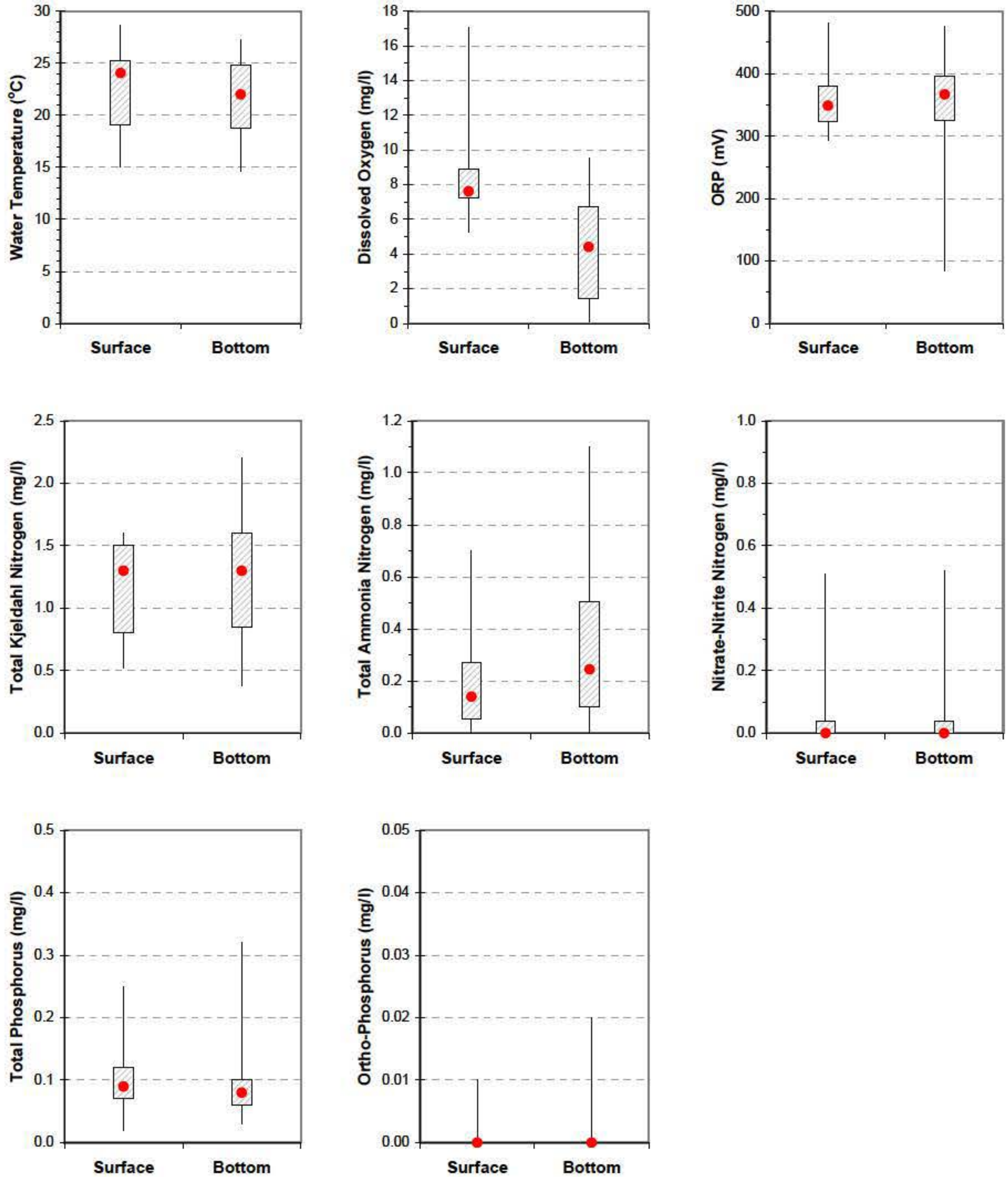

Plate 126. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in East Twin Reservoir at site ETNLKND1 during the summer months of 2002 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

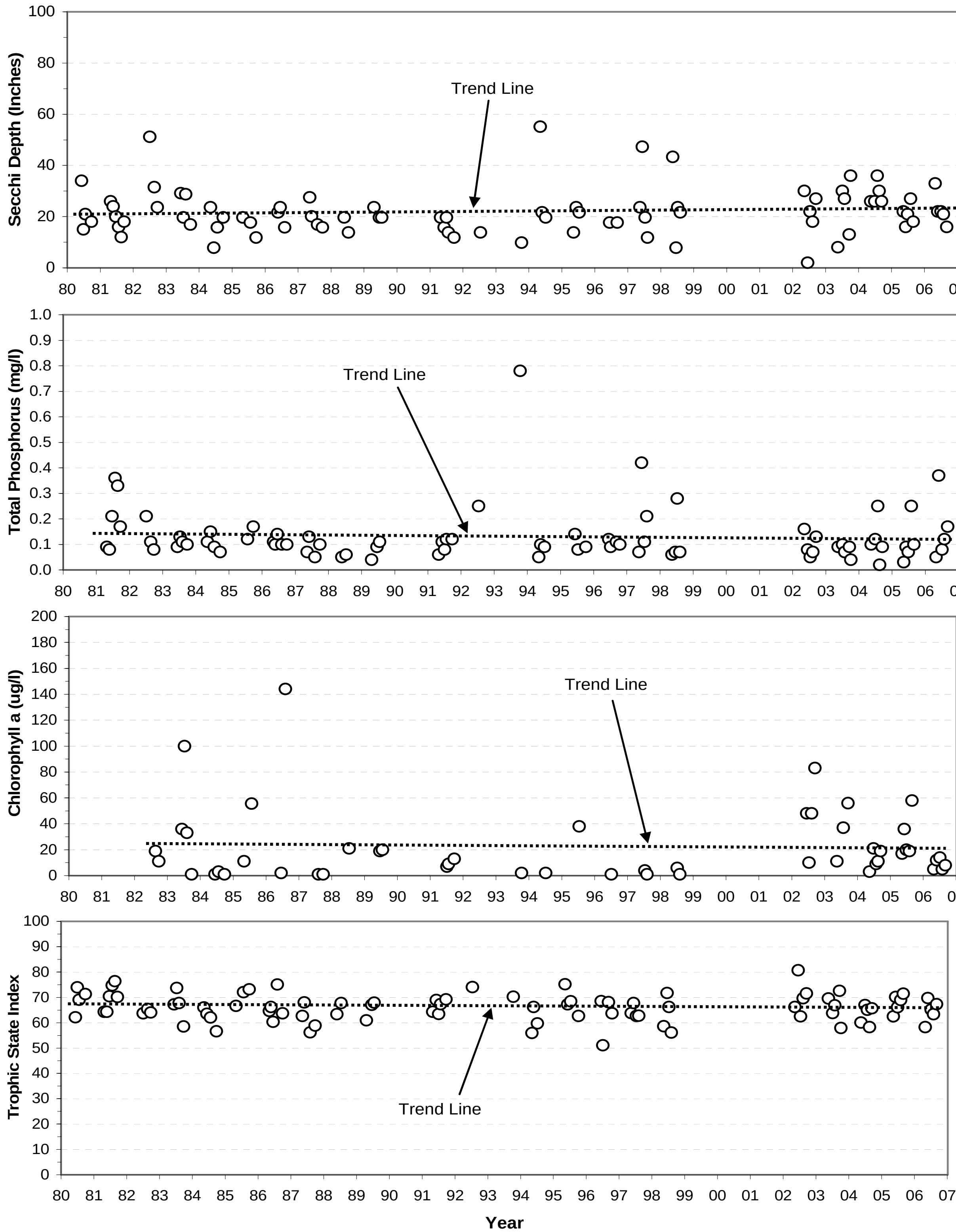

Plate 127. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in East Twin Reservoir at the near-dam, ambient site (i.e., site ETNLKND1) over the 27-year period of 1980 to 2006.

Plate 128. Summary of runoff water quality conditions monitored in the main tributary inflow to East Twin Reservoir at monitoring site ETNNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	9	4.3	3.9	1.5	9.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	1.89	1.40	0.25	4.36	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	9	1.32	1.22	0.44	2.83	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	703	312	89	2,640	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	9	4.16	1.13	0.13	29.92	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	9	18.55	4.00	0.21	114.51	330(1), 12(2)	4	44%
Metolachlor, Total (ug/l)***	0.05	9	5.87	2.03	0.25	36.63	390(1), 100(2)	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.

** (1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

*** Immunoassay analysis.

Plate 129. Summary of water quality conditions monitored in West Twin Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site WTNLKND1) from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	18	1340.0	1340.0	1337.9	1341.5	-----	-----	-----
Water Temperature (C)	0.1	44	23.1	24.4	15.6	31.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	44	6.7	6.4	2.9	15.3	≥ 5.0	6	14%
Dissolved Oxygen (% Sat.)	0.1	44	81.5	74.6	36.2	208.1	-----	-----	-----
Specific Conductance (umho/cm)	1	44	505	484	417	651	-----	-----	-----
pH (S.U.)	0.1	44	8.3	8.3	7.7	10.2	≥6.5 & ≤9.0	1	2%
Turbidity (NTUs)	0.1	22	161.4	101.0	48.0	617.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	19	357	363	171	489	-----	-----	-----
Secchi Depth (in.)	1	15	7	6	3	10	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	131	136	46	180	-----	-----	-----
Ammonia, Total (mg/l)	0.01	15	0.47	0.43	n.d.	1.30	4.71 (1,2), 0.81 (1,3)	0, 2	0%, 13%
Chlorophyll *a* (ug/l) – Field Probe	1	7	139	142	113	150	44(5)	7	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	17	42	30	6	139	44(5)	5	29%
Hardness, Total (mg/l)	0.4	6	213	190	176	287	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	28	2.5	2.0	n.d.	9.6	-----	-----	-----
Nitrogen, Total (mg/)	0.1	26	2.8	2.2	0.8	9.6	1.46(5)	21	81%
Nitrate-Nitrite N, Total (mg/l)	0.02	26	-----	n.d.	n.d.	0.86	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	28	0.34	0.29	0.08	1.30	0.139(5)	27	96%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	28	-----	0.01	n.d.	0.12	-----	-----	-----
Suspended Solids, Total (mg/l)	4	28	109	74	16	456	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	3	12	9	5	23	340(2), 16.7(3,4)	0, 1	0%, 33%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d,	11.0(2), 0.4(3)	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,002(2), 130(3)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	4	24.6(2), 15.5(3)	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	129(2), 5.0(3)	0, 1	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	4	806(2), 90(3)	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	10.4(2)	0	0%
Thallium (ug/l)	6	2	-----	n.d.	n.d.	n.d.	1,400(2), 6.3(3)	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	4	n.d.	8	202(2,3)	0	0%
Microcystins, Total (ug/l)	0.2	2	0.9	0.9	n.d.	1.9	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	17	2.20	2.02	0.61	4.81	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)***	0.05	17	4.91	2.61	0.54	32.80	330(2), 12(3)	0, 2	0%, 12%
Metolachlor, Total (ug/l)***	0.05	17	1.27	0.81	0.13	4.88	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)****	0.05	3					*****	0	0%
Acetochlor			0.77	0.70	0.10	1.50			
Alachlor			-----	n.d.	n.d.	0.55			
Atrazine			4.97	6.30	0.60	8.00			
Metolachlor			0.66	0.37	0.20	1.40			
Metribuzin			-----	n.d.	n.d.	0.10			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 24.4 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 190 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

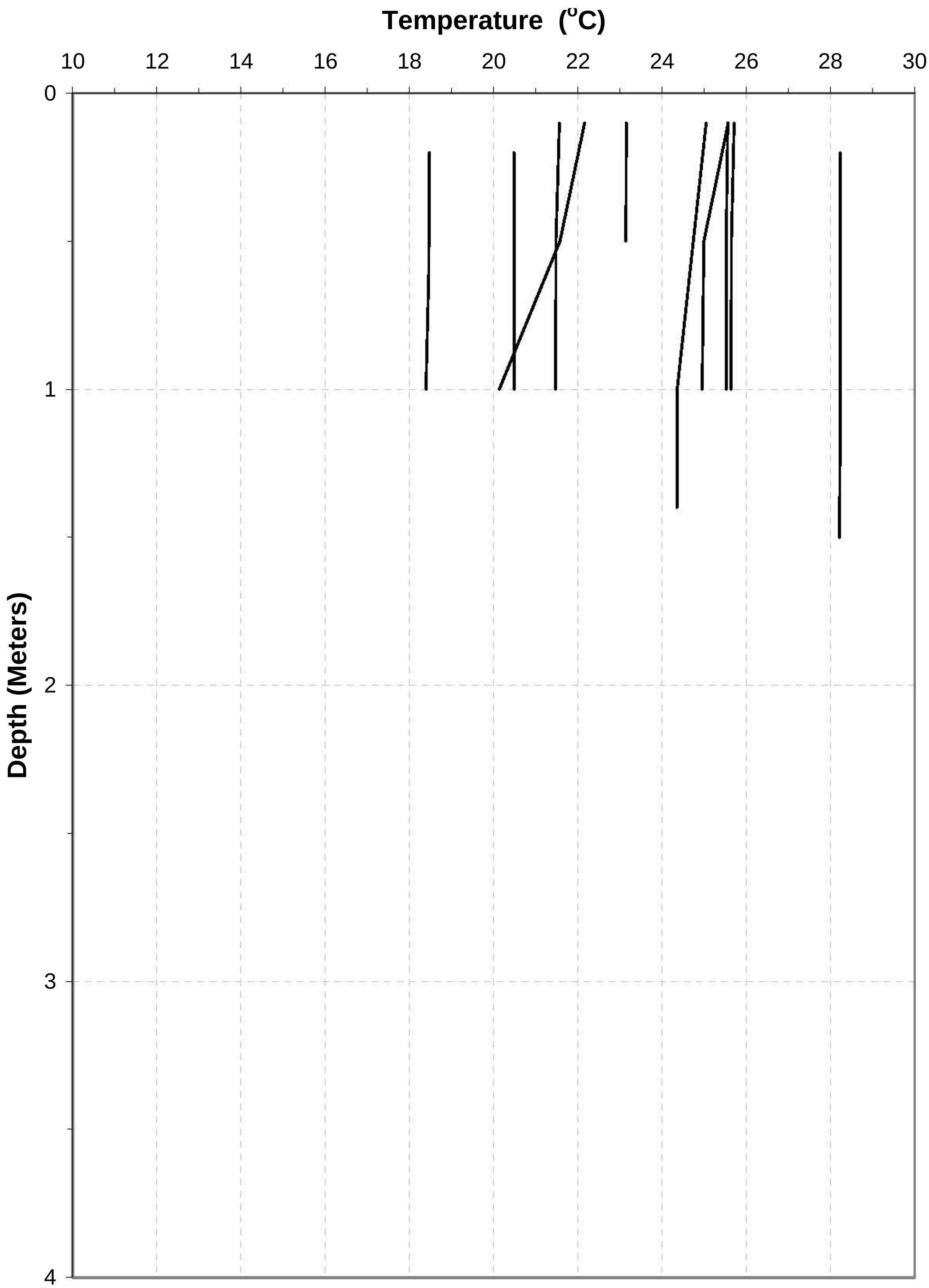

Plate 130. Temperature depth profiles for West Twin Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WTNLKND1) during the summer over the 4-year period of 2002 through 2005.

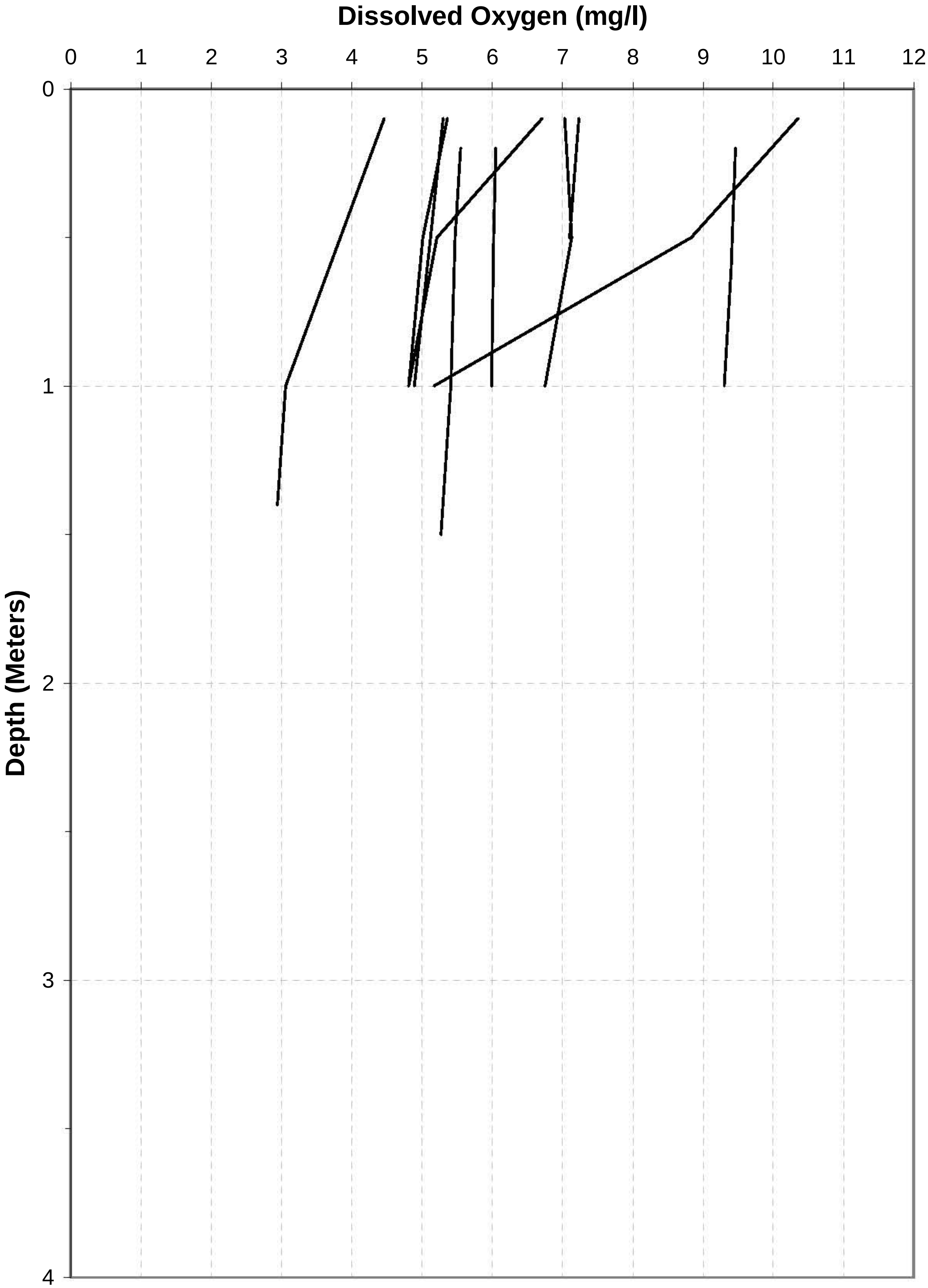

Plate 131. Dissolved oxygen depth profiles for West Twin Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WTNLKND1) during the summer over the 4-year period of 2003 through 2005.

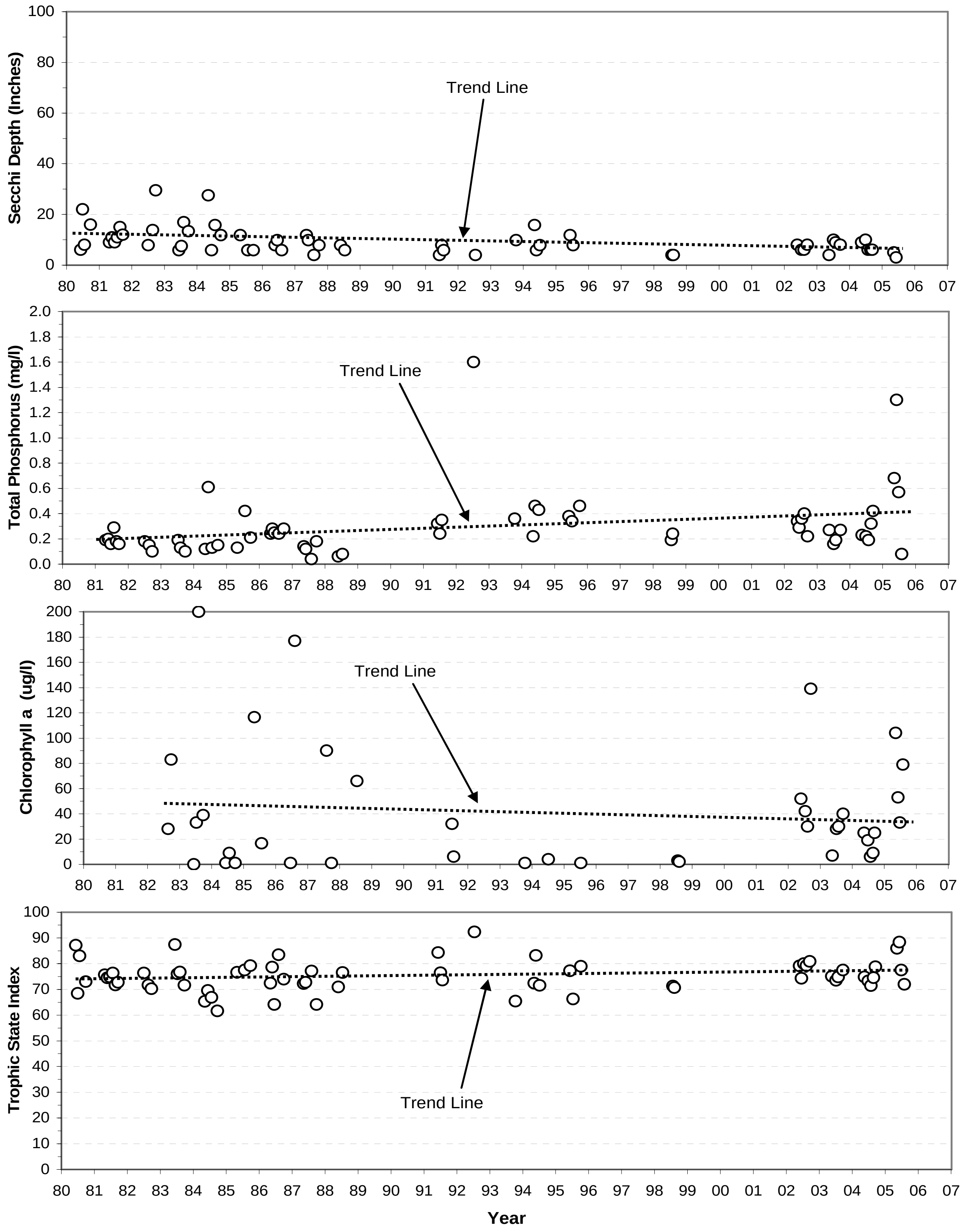

Plate 132. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in West Twin Reservoir at the near-dam, ambient site (i.e., site WTNLKND1) over the 26-year period of 1980 to 2005.

Plate 133. Summary of runoff water quality conditions monitored in the main tributary inflow to West Twin Reservoir at monitoring site WTNNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	10	6.0	4.1	2.5	22.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	10	1.70	1.29	0.80	4.37	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	10	1.67	1.34	0.69	4.59	-----	-----	-----
Suspended Solids, Total (mg/l)	4	10	686	578	76	1,390	-----	-----	-----
Acetochlor, Total (ug/l)***	0.05	1	66.66	66.66	66.66	66.66			
Alachlor, Total (ug/l)***	0.05	9	8.83	1.46	0.28	42.13	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	10	26.71	14.36	0.16	84.84	330(1), 12(2)	5	50%
Metolachlor, Total (ug/l)***	0.05	10	7.44	2.35	0.20	23.54	390(1), 100(2)	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.

** (1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

*** Immunoassay analysis.

Plate 134. Summary of water quality conditions monitored in Wagon Train Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site WAGLKND1) from May to September during the 4-year period 2003 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1285.6	1285.9	1284.0	1287.8	-----	-----	-----
Water Temperature (C)	0.1	164	22.1	22.7	14.9	30.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	164	6.3	6.3	0.0	12.6	≥ 5.0	41	25%
Dissolved Oxygen (% Sat.)	0.1	157	74.0	74.2	0.0	149.7	-----	-----	-----
Specific Conductance (umho/cm)	1	157	335	322	261	450	-----	-----	-----
pH (S.U.)	0.1	157	8.3	8.2	7.3	9.4	≥6.5 & ≤9.0	5	3%
Turbidity (NTUs)	0.1	117	28.4	23.1	1.8	117.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	131	380	383	69	480	-----	-----	-----
Secchi Depth (in.)	1	20	22	17	9	60	-----	-----	-----
Alkalinity, Total (mg/l)	7	39	157	163	90	200	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	-----	0.14	n.d.	1.40	5.72 [(1,2)], 1.06 [(1,3)]	0, 2	0%, 6%
Chlorophyll *a* (ug/l) – Field Probe	1	52	34	38	4	61	16[(5)]	47	90%
Chlorophyll *a* (ug/l) – Lab Determined	1	18	21	14	1	100	16[(5)]	6	33%
Hardness, Total (mg/l)	0.4	10	132	135	114	145	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	40	1.3	1.4	n.d.	2.1	-----	-----	-----
Nitrogen, Total (mg/)	0.1	40	1.4	1.4	n.d.	2.9	1.54[(5)]	11	28%
Nitrate-Nitrite N, Total (mg/l)	0.02	40	-----	n.d.	n.d.	1.10	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	40	0.30	0.29	0.09	0.55	0.143[(5)]	32	80%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	40	0.18	0.19	n.d.	0.41	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	13	14	n.d.	27	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[(2)], 30[(3)]	0	0%
Arsenic, Dissolved (ug/l)	3	4	20	20	16	22	340[(2)], 16.7[(3,4)]	0, 3	0%, 75%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[(2)], 5.3[(3)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	7.9[(2)], 0.3[(3)]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	757[(2)], 99[(3)]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	17.86[(2)], 11.6[(3)]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	89[(2)], 3.5[(3)]	0, 1	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[(2)]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[(3,4)]	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	604[(2)], 67[(3)]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20[(2)], 5[(3)]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	5.8[(2)]	0	0%
Thallium (ug/l)	6	2	-----	n.d.	n.d.	n.d.	1,400[(2)], 6.3[(3)]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	4	n.d.	8	151[(2,3)]	0	0%
Microcystins, Total (ug/l)	0.2	9	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	19	0.18	0.19	n.d.	0.35	760[(2)], 76[(3)]	0	0%
Atrazine, Total (ug/l)***	0.05	20	0.49	2.49	n.d.	9.15	330[(2)], 12[(3)]	0	0%
Metolachlor, Total (ug/l)***	0.05	19	0.60	0.52	0.12	2.02	390[(2)], 100[(3)]	0	0%
Pesticide Scan (ug/l)****	0.05	4					*****	0	0%
Acetochlor			-----	0.10	n.d.	0.30			
Alachlor			-----	n.d.	n.d.	0.10			
Atrazine			3.42	1.25	0.57	10.60			
Metolachlor			-----	n.d.	n.d.	2.50			
Propazine			-----	n.d.	n.d.	0.20			

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [(1)] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 22.7 respectively.
[(2)] Acute criterion for aquatic life.
[(3)] Chronic criterion for aquatic life.
[(4)] Human health criterion for surface waters.
[(5)] Nutrient criteria.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 135 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 135. Summary of water quality conditions monitored in Wagon Train Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site WAGLKML1) from May to September during the 4-year period 2003 through 2006. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	19	1285.7	1286.0	1284.0	1287.8	-----	-----	-----
Water Temperature (C)	0.1	138	22.3	23.0	15.0	29.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	138	7.1	6.9	1 2	14.5	≥ 5.0	22	16%
Dissolved Oxygen (% Sat.)	0.1	132	83.6	82.6	12.6	164.4	-----	-----	-----
Specific Conductance (umho/cm)	1	132	337	323	253	452	-----	-----	-----
pH (S.U.)	0.1	132	8.4	8.4	7 5	9.6	≥6.5 & ≤9.0	5	4%
Turbidity (NTUs)	0.1	98	27.1	22.0	1.0	107.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	111	374	367	244	484	-----	-----	-----
Secchi Depth (in.)	1	20	19	17	7	72	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	39	31	35	4	49	16(5)	35	90%

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** Immunoassay analysis.

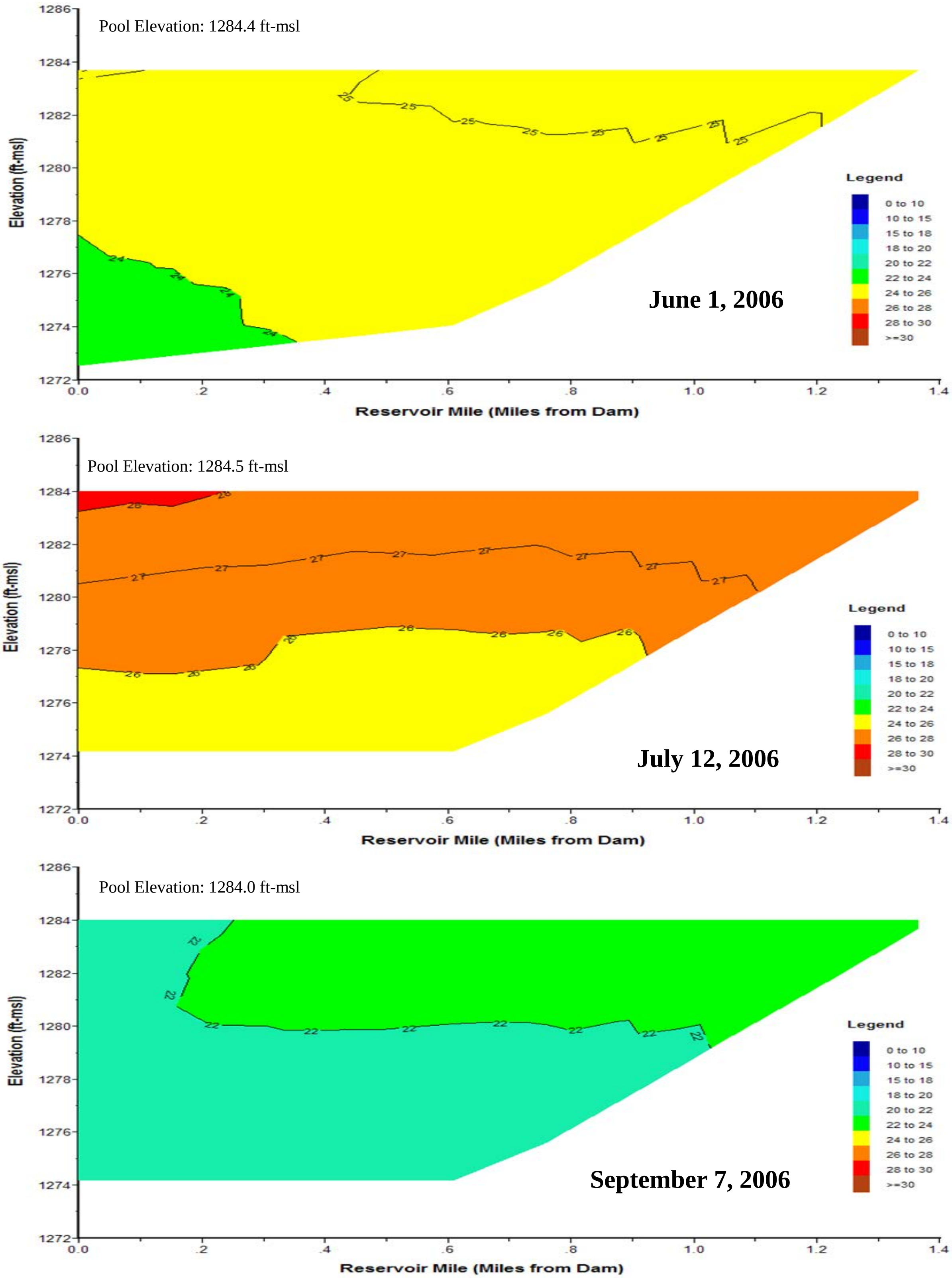

Plate 136. Longitudinal water temperature (°C) contour plots of Wagon Train Reservoir based on depth-profile water temperatures measured at sites WAGLKND1 and WAGLKML1 in June, July, and September 2006.

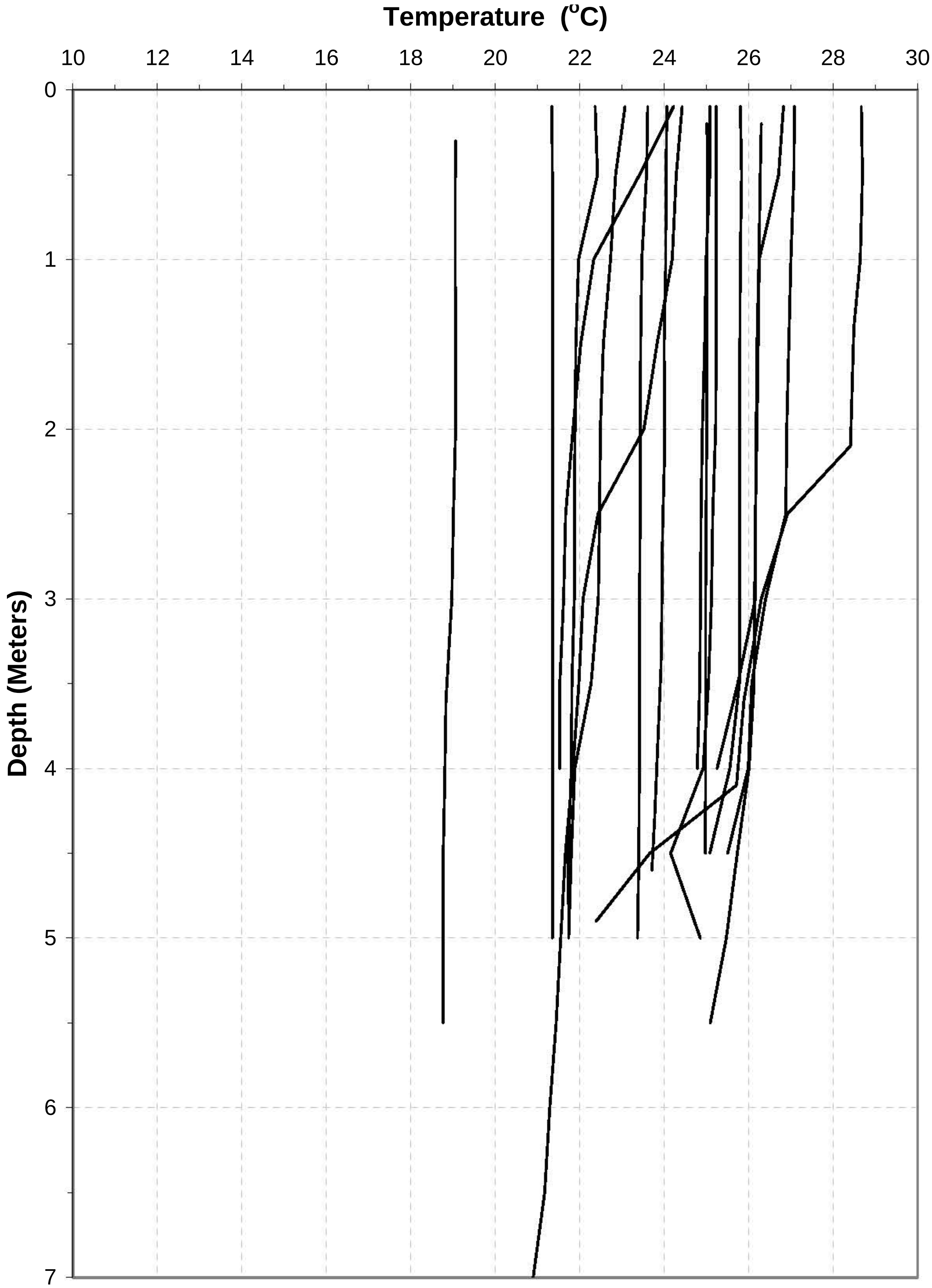

Plate 137. Temperature depth profiles for Wagon Train Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WAGLKND1) during the summer over the 4-year period of 2003 through 2006.

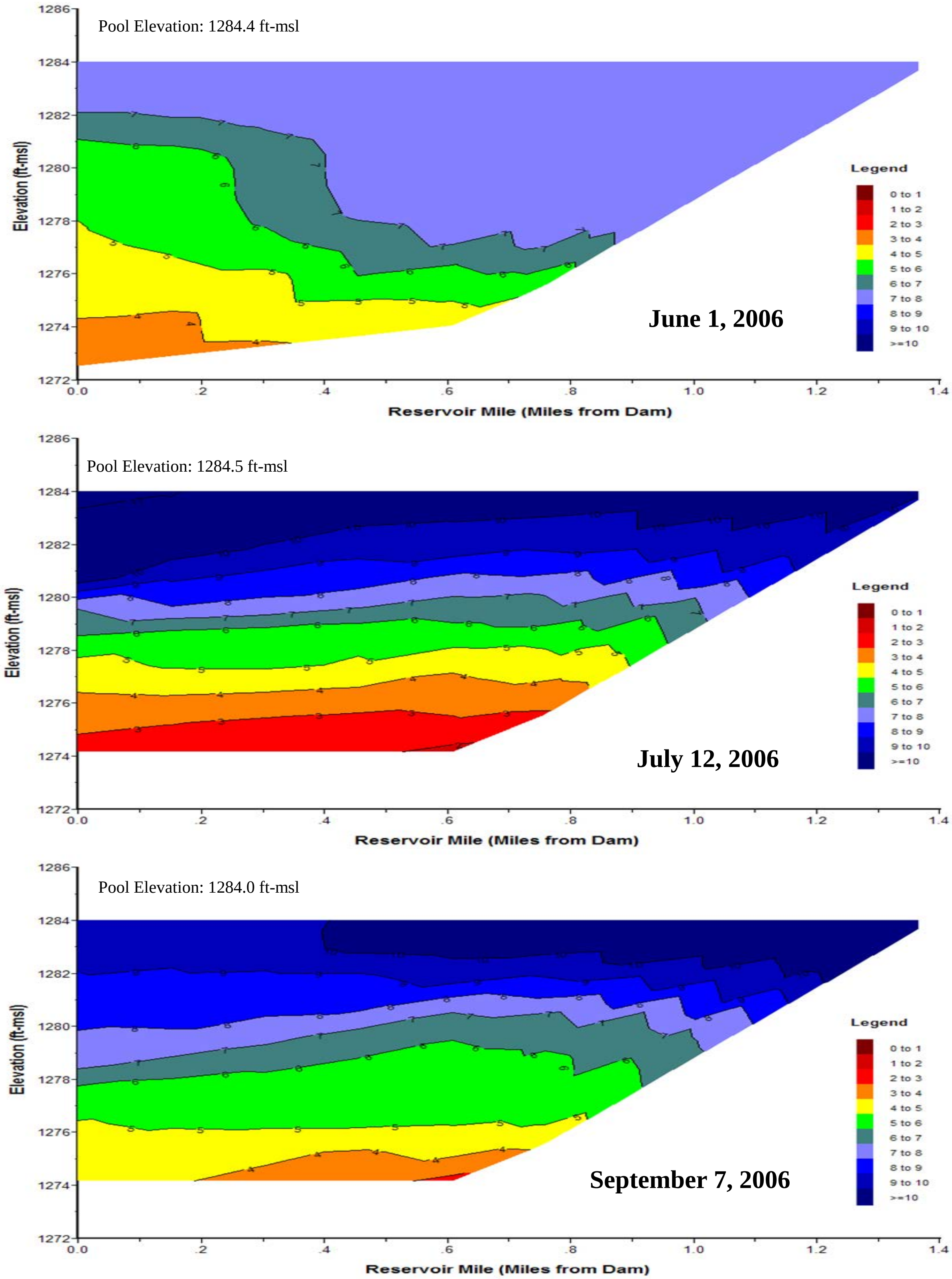

Plate 138. Longitudinal dissolved oxygen (mg/l) contour plots of Wagon Train Reservoir based on depth-profile dissolved oxygen concentrations measured at sites WAGLKND1 and WAGLKML1 in June, July, and September 2006.

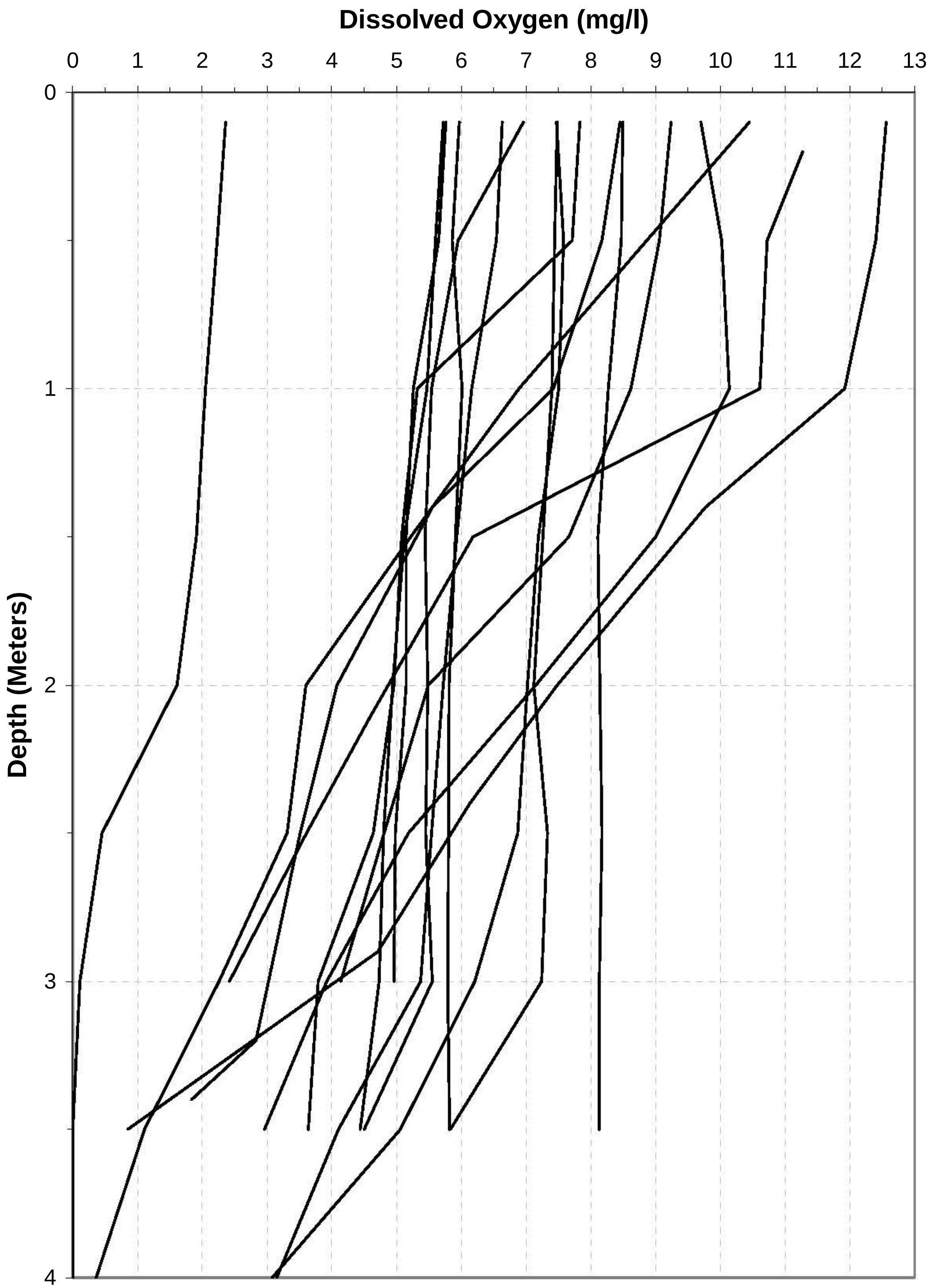

Plate 139. Dissolved oxygen depth profiles for Wagon Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., WAGLKND1) during the summer over the 4-year period of 2003 through 2006.

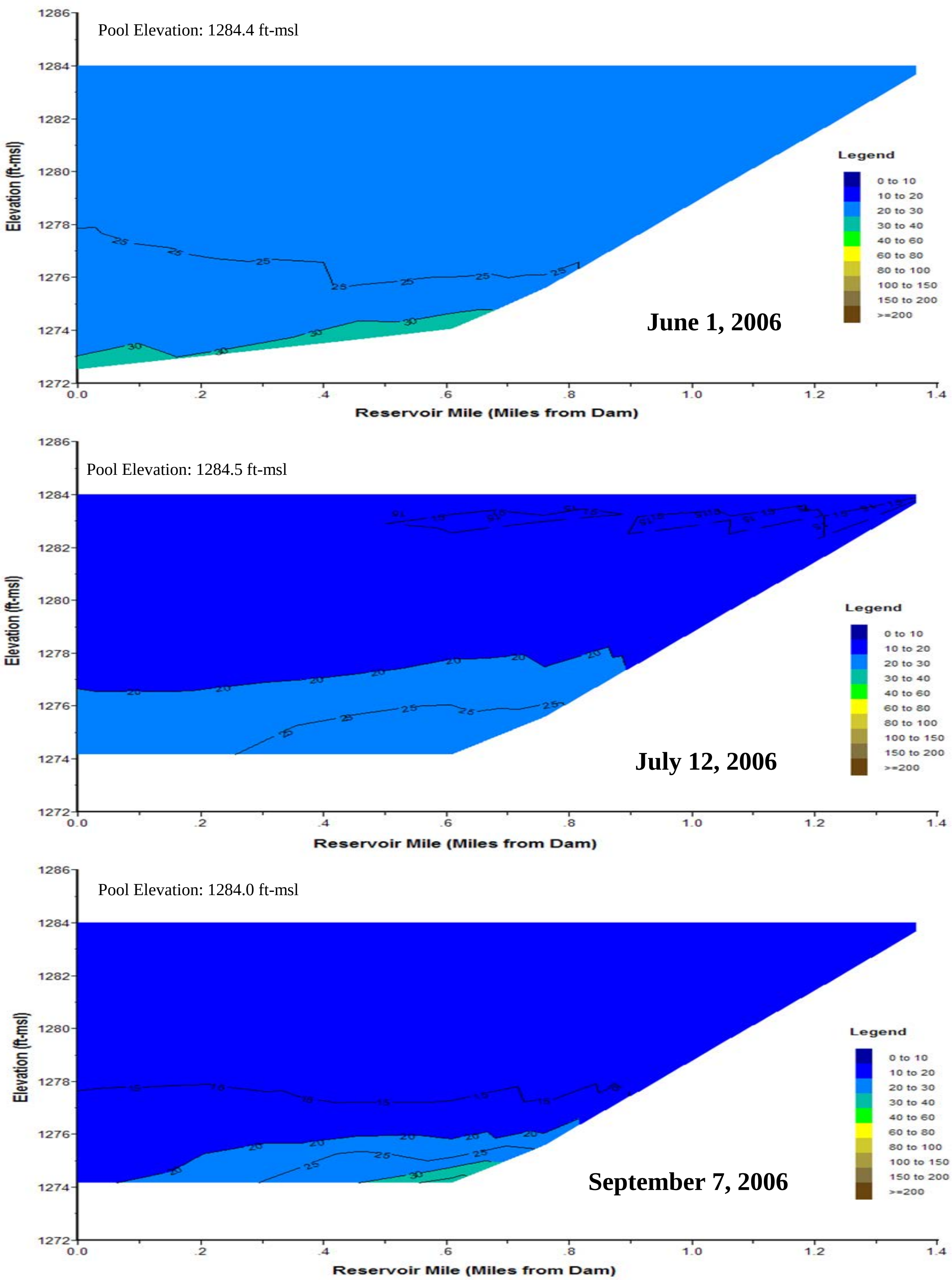

Plate 140. Longitudinal turbidity (NTU) contour plots of Wagon Train Reservoir based on depth-profile turbidity levels measured at sites WAGLKND1 and WAGLKML1 in June, July, and September 2006.

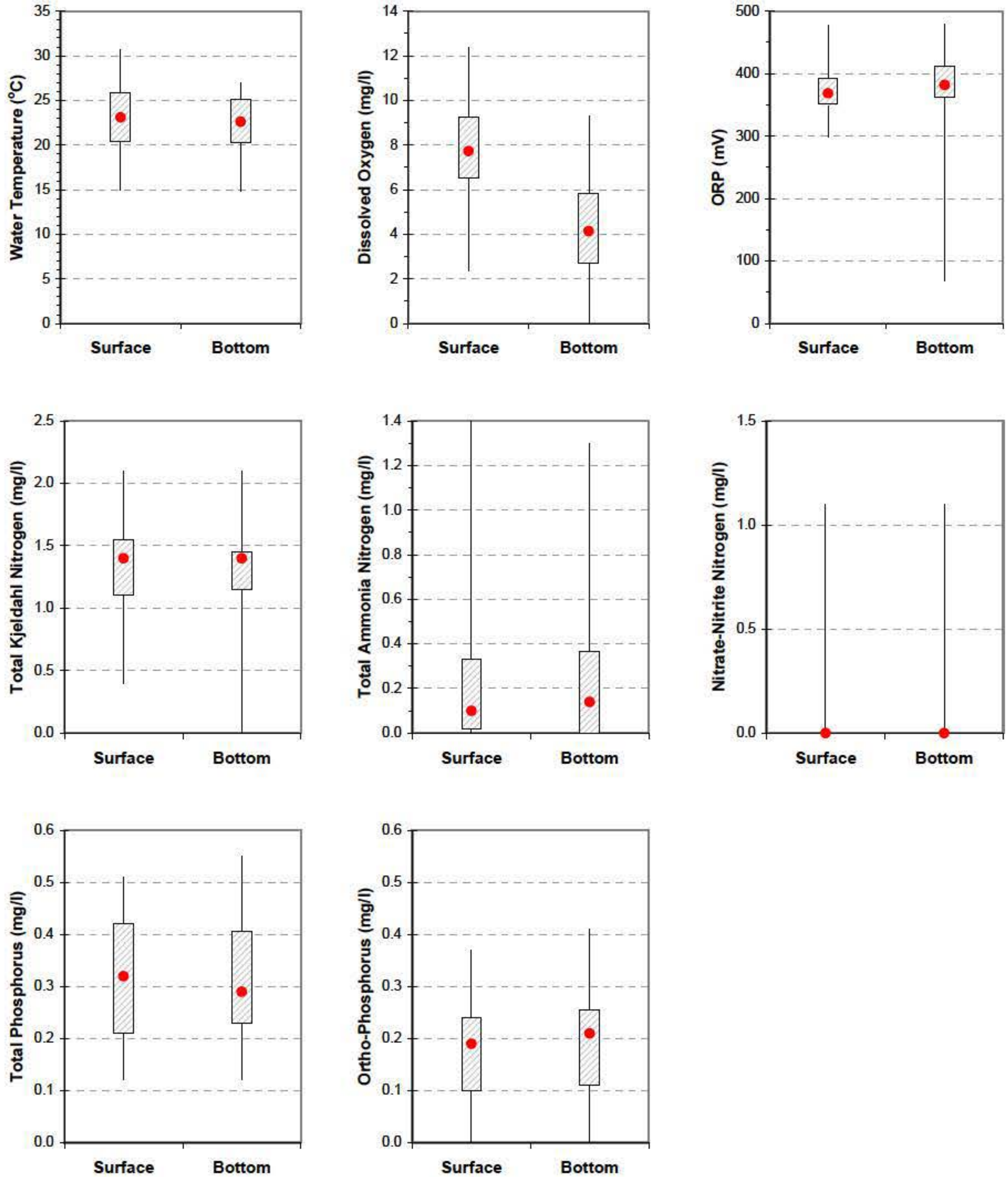

Plate 141. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and ortho-phosphorus measured in Wagon Train Reservoir at site WAGLKND1 during the summer months of 2003 through 2006. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

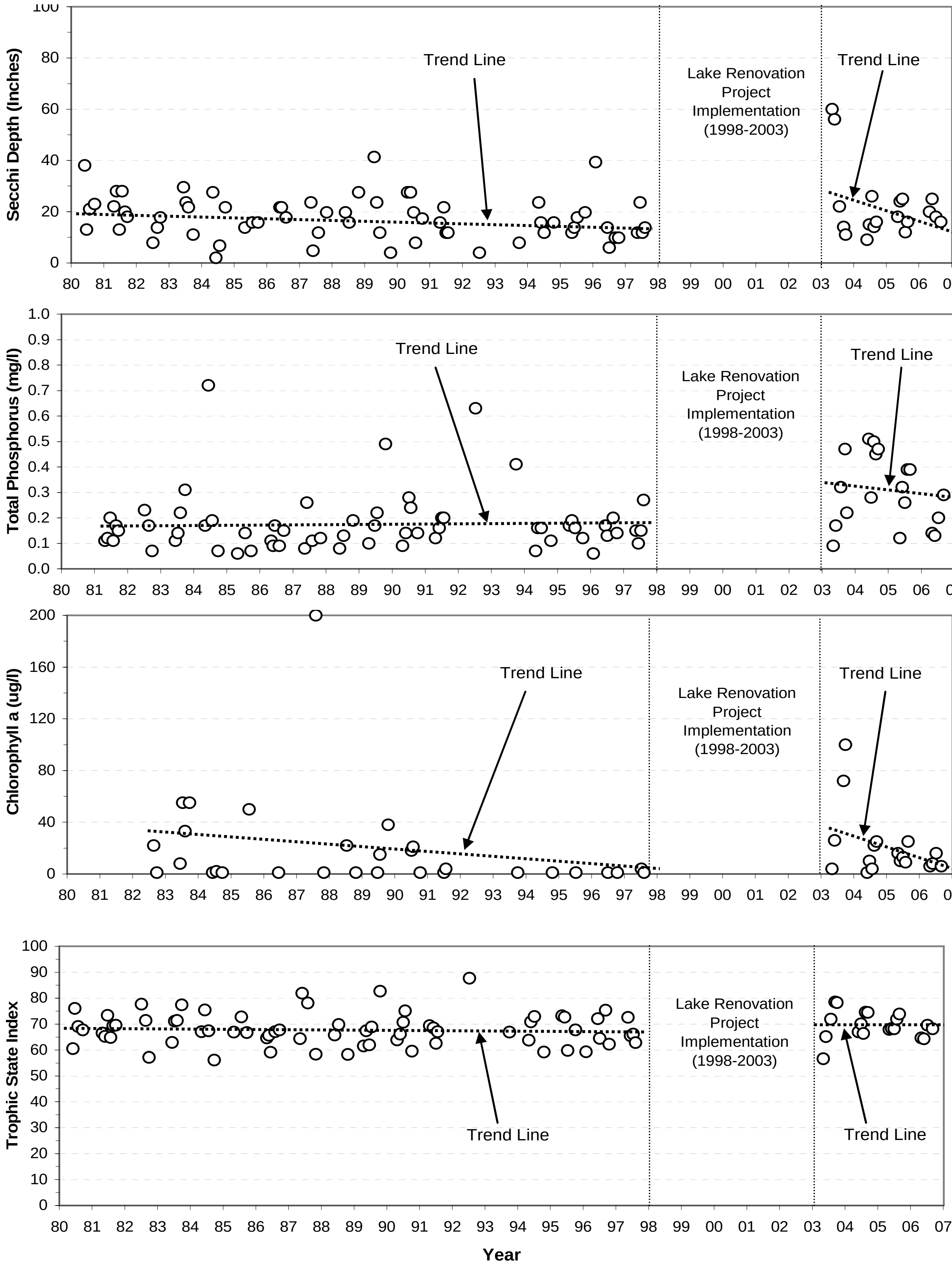

Plate 142. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Wagon Train Reservoir at the near-dam, ambient site (i.e., site WAGLKND1) over the 27-year period of 1980 to 2006.

Plate 143. Summary of runoff water quality conditions monitored in the main tributary inflow to Wagon Train Reservoir at monitoring site WAGNF1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	7	4.1	4.8	1.8	6.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	7	3.84	1.74	0.34	16.22	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	7	1.20	1.02	0.61	2.08	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	3	0.27	0.25	0.02	0.53	-----	-----	-----
Suspended Solids, Total (mg/l)	4	7	632	360	96	1,840	-----	-----	-----
Turbidity (NTU)	0.1	2	1,334	1,334	526	2,143	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	6	0.41	0.42	0.12	0.67	760[(1)], 76[(2)]	0	0%
Atrazine, Total (ug/l)***	0.05	7	16.37	7.48	0.22	52.14	330[(1)], 12[(2)]	3	43%
Metolachlor, Total (ug/l)***	0.05	7	4.36	0.98	0.42	19.03	390[(1)], 100[(2)]	0	0%
E. coli (cfu/100ml)	1	3	17,184	25,000	1,553	25,000	-----	-----	-----

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** [(1)] Acute criterion for aquatic life.
[(2)] Chronic criterion for aquatic life.
*** Immunoassay analysis.

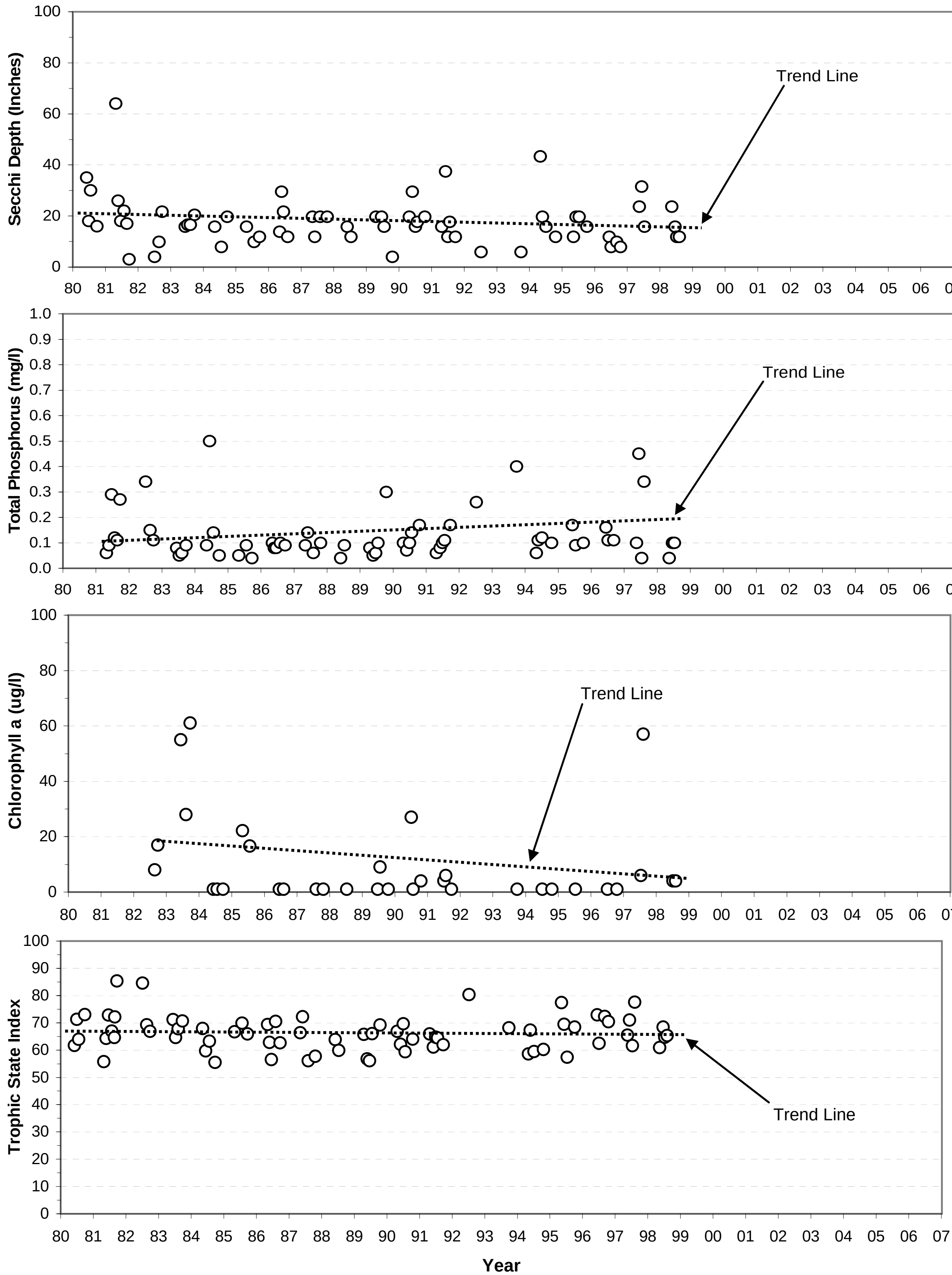

Plate 144. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Yankee Hill Reservoir at the near-dam, ambient site (i.e., site YANLKND1) over the 19-year period of 1980 to 1998.

Plate 145. Summary of runoff water quality conditions monitored in the west tributary inflow to Yankee Hill Reservoir at monitoring site YANNFWST1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	7	5.0	5.3	2.3	7.2	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	7	8.31	6.39	1.08	16.39	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	7	1.37	1.45	0.44	2.11	-----	-----	-----
Suspended Solids, Total (mg/l)	4	7	896	890	284	1,670	-----	-----	-----
Turbidity (NTU)	0.1	1	1,680	1,680	1,680	1,680	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	7	1.03	0.47	0.08	3.71	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	7	41.06	20.68	0.49	175.74	330(1), 12(2)	5	71%
Metolachlor, Total (ug/l)***	0.05	7	10.63	4.09	1.16	32.67	390(1), 100(2)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 146. Summary of runoff water quality conditions monitored in the south tributary inflow to Yankee Hill Reservoir at monitoring site YANNFSTH1 during the period 2002 through 2006**.**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Kjeldahl N, Total (mg/l)	0.1	9	5.2	4.4	1.5	11.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	9	6.23	3.80	0.39	26.13	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	9	1.54	1.09	0.56	3.42	-----	-----	-----
Suspended Solids, Total (mg/l)	4	9	1,244	720	94	2,910	-----	-----	-----
Turbidity (NTU)	0.1	2	1,466	1,466	386	2,545	-----	-----	-----
Alachlor, Total (ug/l)***	0.05	8	0.32	0.24	0.08	0.82	760(1), 76(2)	0	0%
Atrazine, Total (ug/l)***	0.05	9	15.10	10.10	0.33	48.48	330(1), 12(2)	4	44%
Metolachlor, Total (ug/l)***	0.05	9	8.22	2.41	0.65	32.56	390(1), 100(2)	0	0%

n.d. = Not detected.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported.
** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
*** Immunoassay analysis.

Plate 147. Summary of water quality conditions monitored in Bowman-Haley Reservoir at the near-dam, deepwater ambient monitoring location (i.e., siteBOWLKND1) from May to September during the 3-year period 2002 through 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	15	2751.6	2751.4	2749.7	2753.6	-----	-----	-----
Water Temperature (C)	0.1	203	17.0	18.1	6.4	23.5	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	203	7.5	7.4	3.3	10.9	≥ 5.0	15	7%
Dissolved Oxygen (% Sat.)	0.1	203	83.0	84.7	39.0	111.1	-----	-----	-----
Specific Conductance (umho/cm)	1	203	2,457	2,561	1,938	3,041	-----	-----	-----
pH (S.U.)	0.1	193	8.7	8.7	7.9	9.2	≥7.0 & ≤9.0	35	18%
Turbidity (NTUs)	0.1	85	20.8	16.3	6.6	88.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	85	330	317	196	379	-----	-----	-----
Secchi Depth (in.)	1	12	41	39	8	84	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	338	336	283	396	-----	-----	-----
Ammonia, Total (mg/l)	0.01	18	0.40	0.36	n.d.	0.86	2.20 (1,2), 0.55 (1,3)	0, 4	0%, 22%
Carbon, Total Organic (mg/l)	0.05	14	15.3	16.0	13.9	16.0	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	70	-----	n.d.	n.d.	19	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	7	-----	5	n.d.	71	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	356	342	298	391	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	28	1.3	1.3	0.5	2.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	28	-----	0.07	n.d.	0.32	1.0	0	0%
Phosphorus, Total (mg/l)	0.01	28	0.09	0.09	0.03	0.17	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	26	-----	0.01	n.d.	0.11	-----	-----	-----
Suspended Solids, Total (mg/l)	4	28	13	14	n.d.	34	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6(4)	0	0%
Arsenic, Dissolved (ug/l)	3	1	3	3	3	3	340(2), 150(3), 50(4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	3	n.d.	6	18.0(2), 6.5(3)	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	4,936(2), 236(3)	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	44.6(2), 26.7(3)	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	391(2), 15.2(3)	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	1,328(2), 148(3)	0	0%
Selenium, Total (ug/l)	2	1	-----	n.d.	n.d.	n.d.	20(2), 5(3), 50(4)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	33.6(2)	0	0%
Zinc, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	340(2,3)	0	0%
Alachlor, Total (ug/l)***	0.05	9	-----	n.d.	n.d.	n.d.	2(4)	0	0%
Atrazine, Total (ug/l)***	0.05	9	-----	n.d.	n.d.	0.07	3(4)	0	0%
Metolachlor, Total (ug/l)***	0.05	9	-----	n.d.	n.d.	0.10	40(4)	0	0%
Pesticide Scan (ug/l)****	0.05	4	-----				*****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.7 and 18.1 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
Note: North Dakota's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 342 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 148. Summary of water quality conditions monitored in Bowman-Haley Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site BOWLKMLN1) from May to September during 2003 and 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	9	2751.6	2751.3	2749.7	2753.6	-----	-----	-----
Water Temperature (C)	0.1	105	17.9	18.5	11 5	25.5	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	105	7.5	7.3	2.4	12.5	≥ 5.0	9	9%
Dissolved Oxygen (% Sat.)	0.1	105	84.4	82.5	27 5	144.5	-----	-----	-----
Specific Conductance (umho/cm)	1	105	2,517	2,641	1,942	3.038	-----	-----	-----
pH (S.U.)	0.1	105	8.6	8.7	7 9	9.1	≥7.0 & ≤9.0	13	12%
Turbidity (NTUs)	0.1	50	22.0	21.0	5 2	45.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	52	366	374	296	409	-----	-----	-----
Secchi Depth (in.)	1	9	44	45	14	84	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	42	-----	n.d.	n.d.	13	-----	-----	-----

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

Plate 149. Summary of water quality conditions monitored in Bowman-Haley Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site BOWLKMLS1) from May to September during 2003 and 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	9	2751.6	2751.3	2749.7	2753.6	-----	-----	-----
Water Temperature (C)	0.1	66	17.7	17.8	11.0	25.8	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	66	7.9	8.0	5 5	11.5	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	66	89.6	86.5	63 5	156.5	-----	-----	-----
Specific Conductance (umho/cm)	1	66	2,468	2,622	1,938	3,065	-----	-----	-----
pH (S.U.)	0.1	66	8.7	8.7	8.0	9.1	≥7.0 & ≤9.0	4	2%
Turbidity (NTUs)	0.1	36	29.7	21.9	8 3	73.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	36	347	364	288	382	-----	-----	-----
Secchi Depth (in.)	1	9	29	27	12	46	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	32	4	4	n.d.	7	-----	-----	-----

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

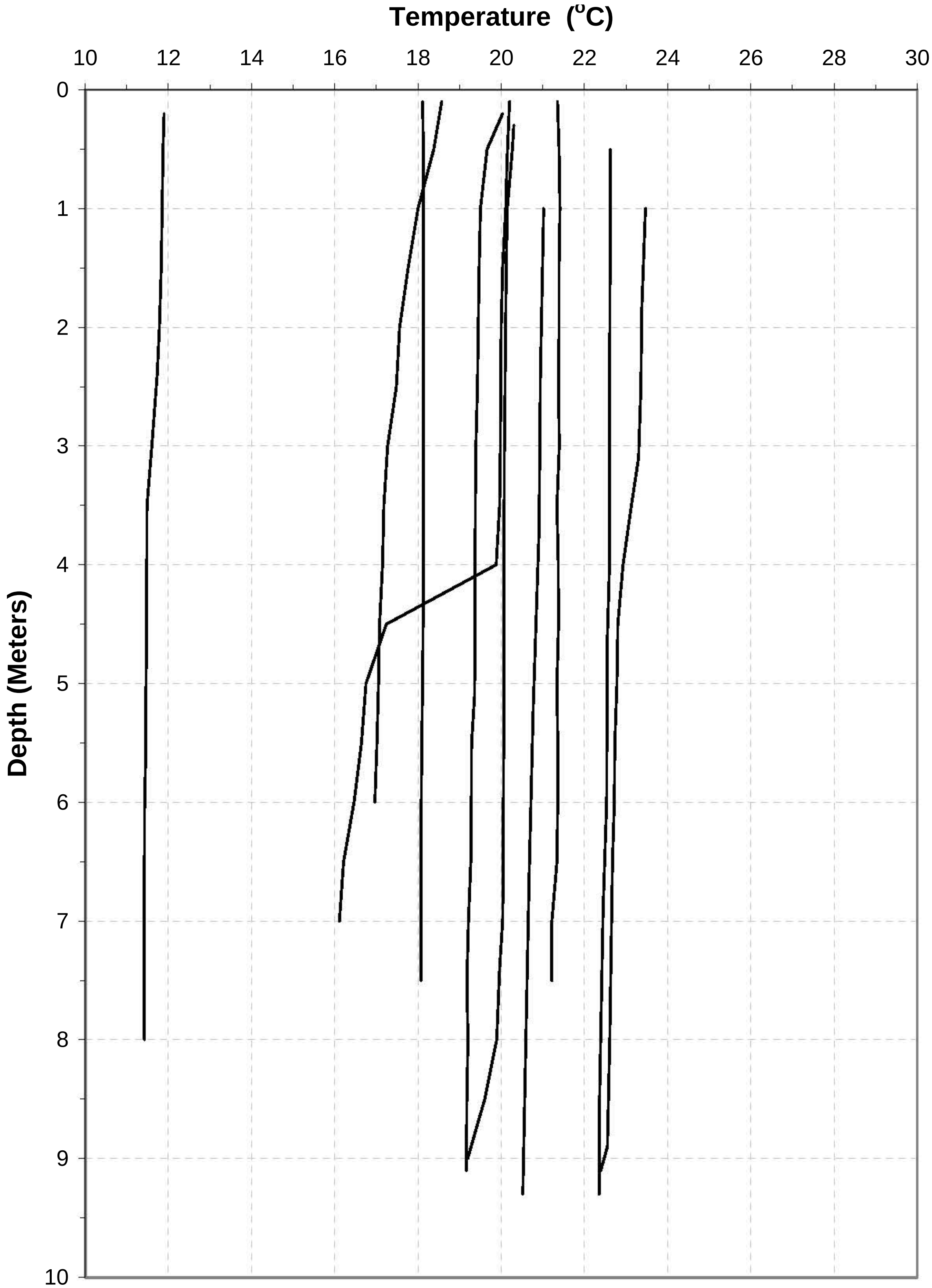

Plate 150. Temperature depth profiles for Bowman-Haley Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BOWLKND1) during the summer over the 3-year period of 2002 through 2004.

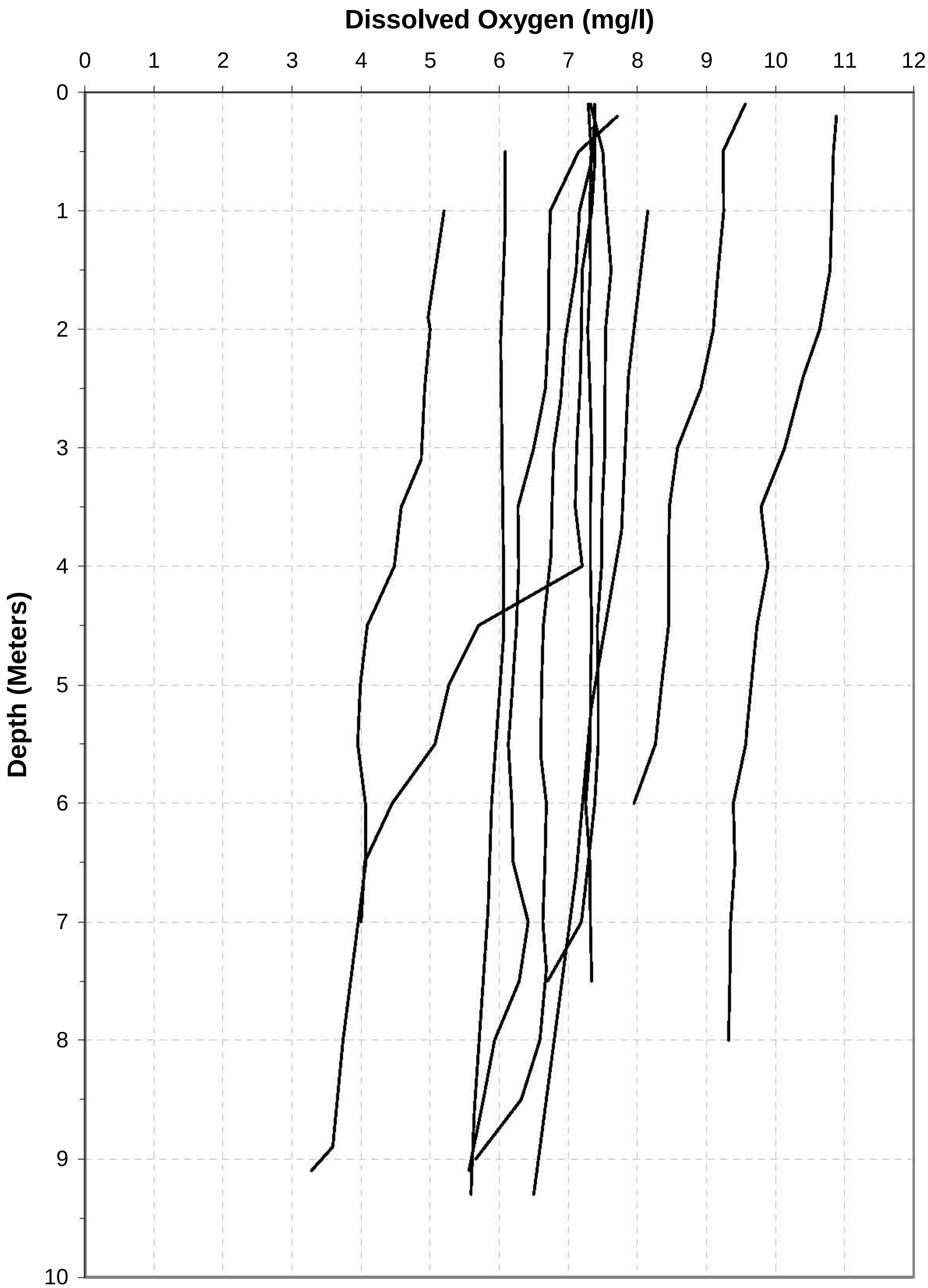

Plate 151. Dissolved Oxygen depth profiles for Bowman-Haley Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., BOWLKND1) during the summer over the 3-year period of 2002 through 2004.

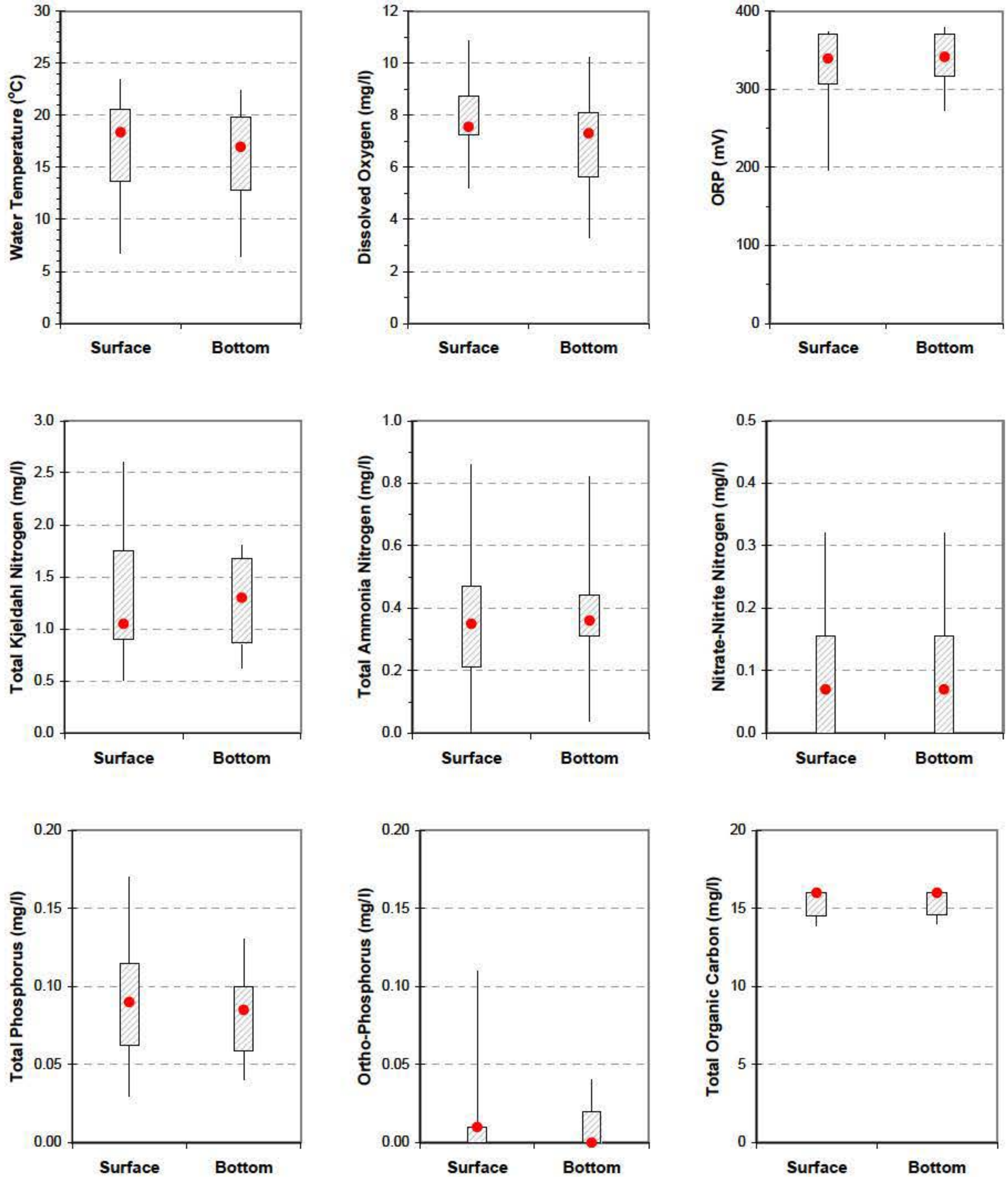

Plate 152. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, ortho-phosphorus, and total organic carbon measured in Bowman-Haley Reservoir at site BOWLKND1 during the summer months of 2003 and 2004. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

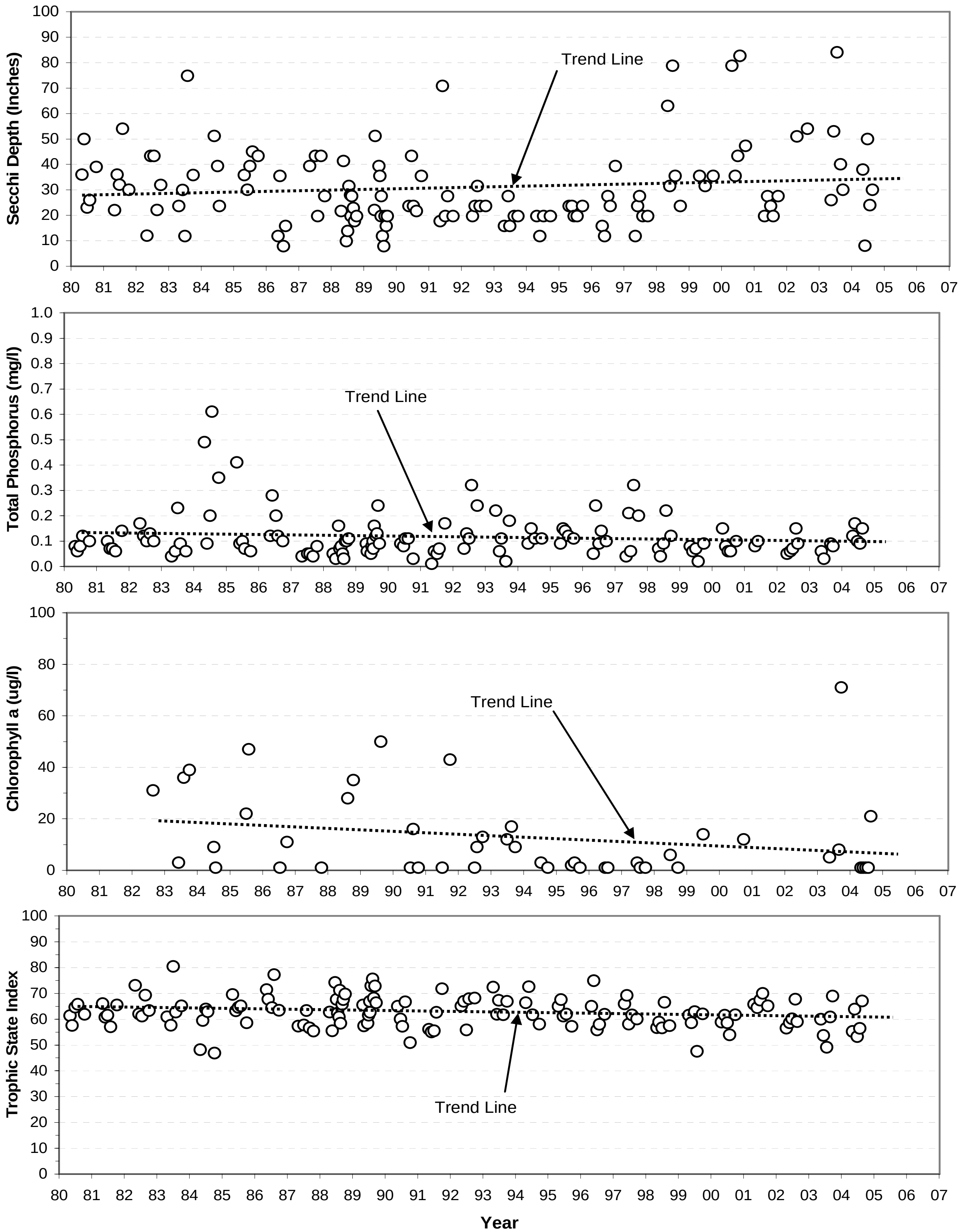

Plate 153. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Bowman-Haley Reservoir at the near-dam, ambient site (i.e., site BOWLKND1) over the 25-year period of 1980 to 2004.

Plate 154. Summary of water quality conditions monitored in Pipestem Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site PIPLKND1) from May to September during the 3-year period 2002 through 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	15	1446.7	1445.0	1442.3	1455.4	-----	-----	-----
Water Temperature (C)	0.1	271	17.9	18.9	6.7	24.8	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	271	6.8	7.3	0.2	10.7	≥ 5.0	42	15%
Dissolved Oxygen (% Sat.)	0.1	271	74.5	82.0	2.1	116.4	-----	-----	-----
Specific Conductance (umho/cm)	1	271	1,198	1,292	925	1,438	-----	-----	-----
pH (S.U.)	0.1	239	8.4	8.4	7.6	8.9	≥7.0 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	163	7.3	7.5	0.9	39.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	164	328	311	48	418	-----	-----	-----
Secchi Depth (in.)	1	15	63	46	20	138	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	301	284	219	402	-----	-----	-----
Ammonia, Total (mg/l)	0.01	20	0.51	0.39	n.d.	1.40	4.71 [1,2], 0.93 [1,3]	0, 2	0%, 10%
Chlorophyll *a* (ug/l) – Field Probe	1	104	-----	11	n.d.	58	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	10	20	16	2	45	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	511	526	461	545	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	29	1.2	1.1	0.8	2.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	29	-----	n.d.	n.d.	0.05	1.0	0	0%
Phosphorus, Total (mg/l)	0.01	29	0.38	0.38	0.13	0.67	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	27	0.27	0.31	n.d.	0.51	-----	-----	-----
Suspended Solids, Total (mg/l)	4	29	-----	6	n.d.	16	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	1	4	4	4	4	340[2], 150[3], 50[4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	3	3	n.d.	6	29.4[2], 9.0[3]	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	7,023[2], 336[3]	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	66.9[2], 38.5[3]	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	676[2], 26.3[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	1.7[2], 0.91[3], 0.05[4]	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	1,825[2], 212[3]	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	64.2[2]	0	0%
Zinc, Dissolved (ug/l)	3	1	4	4	4	4	489[2,3]	0	0%
Alachlor, Total (ug/l)***	0.05	9	-----	n.d.	n.d.	n.d.	2[4]	0	0%
Atrazine, Total (ug/l)***	0.05	9	0.10	0.08	n.d.	0.22	3[4]	0	0%
Metolachlor, Total (ug/l)***	0.05	9	-----	n.d.	n.d.	n.d.	40[4]	0	0%
Pesticide Scan (ug/l)****	0.05	3	-----				*****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 18.9 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
Note: North Dakota's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 526 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 155. Summary of water quality conditions monitored in Pipestem Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site PIPLKML1) from May to September during the 3-year period 2002 through 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	14	1446.6	1444.6	1442 3	1455.4	-----	-----	-----
Water Temperature (C)	0.1	159	18.4	18.4	6 5	25.1	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	159	7.4	7.9	0 3	11.4	≥ 5.0	19	12%
Dissolved Oxygen (% Sat.)	0.1	159	81.9	87.5	3 3	118.6	-----	-----	-----
Specific Conductance (umho/cm)	1	159	1,189	1,297	934	1,437	-----	-----	-----
pH (S.U.)	0.1	136	8.4	8.4	7.6	8.8	≥7 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	92	14.6	11.0	2.4	40.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	92	382	391	295	417	-----	-----	-----
Secchi Depth (in.)	1	11	38	34	15	79	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	71	25	18	n.d.	82	-----	-----	-----

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

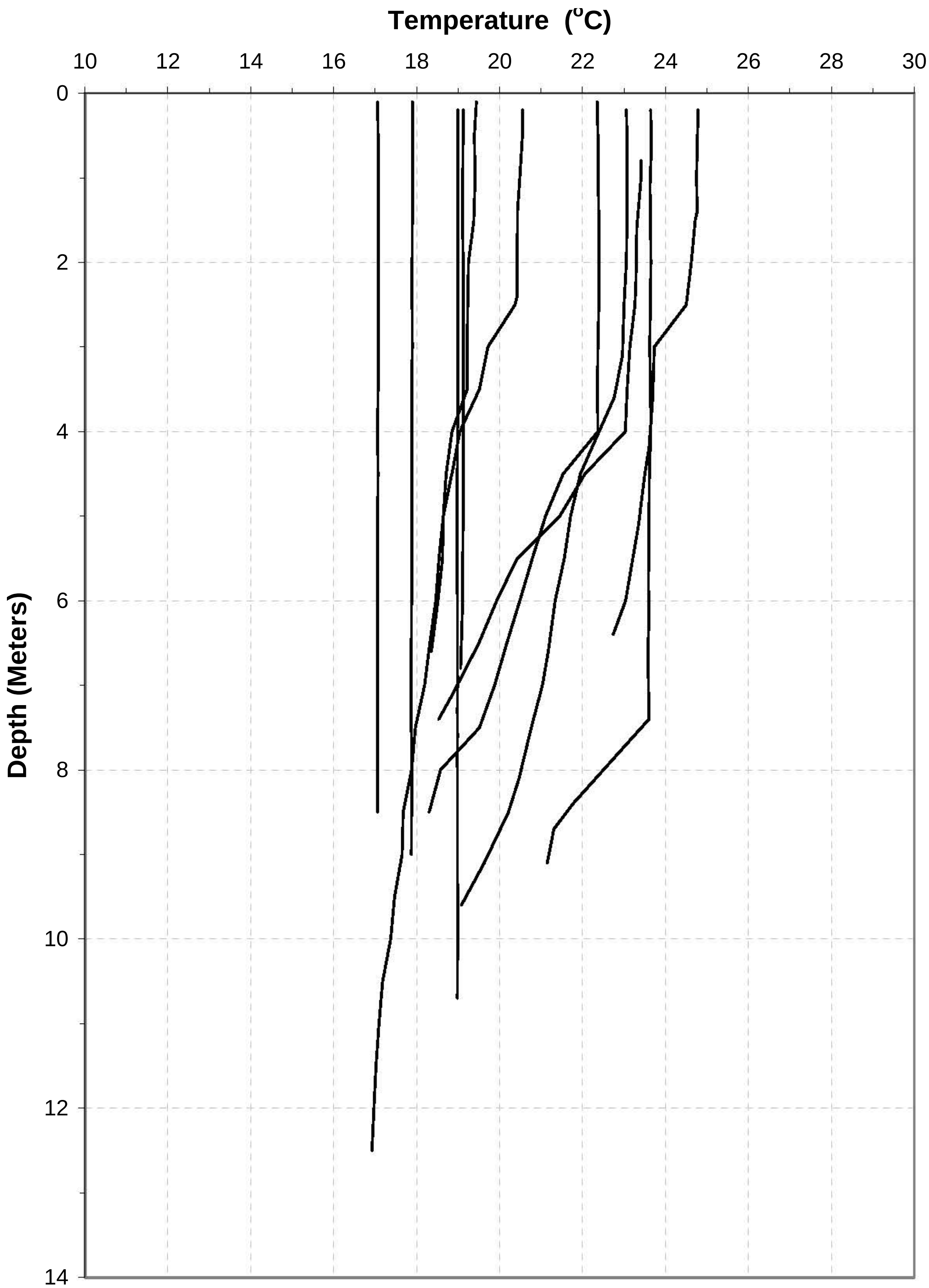

Plate 156. Temperature depth profiles for Pipestem Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., PIPLKND1) during the summer over the 3-year period of 2002 through 2004.

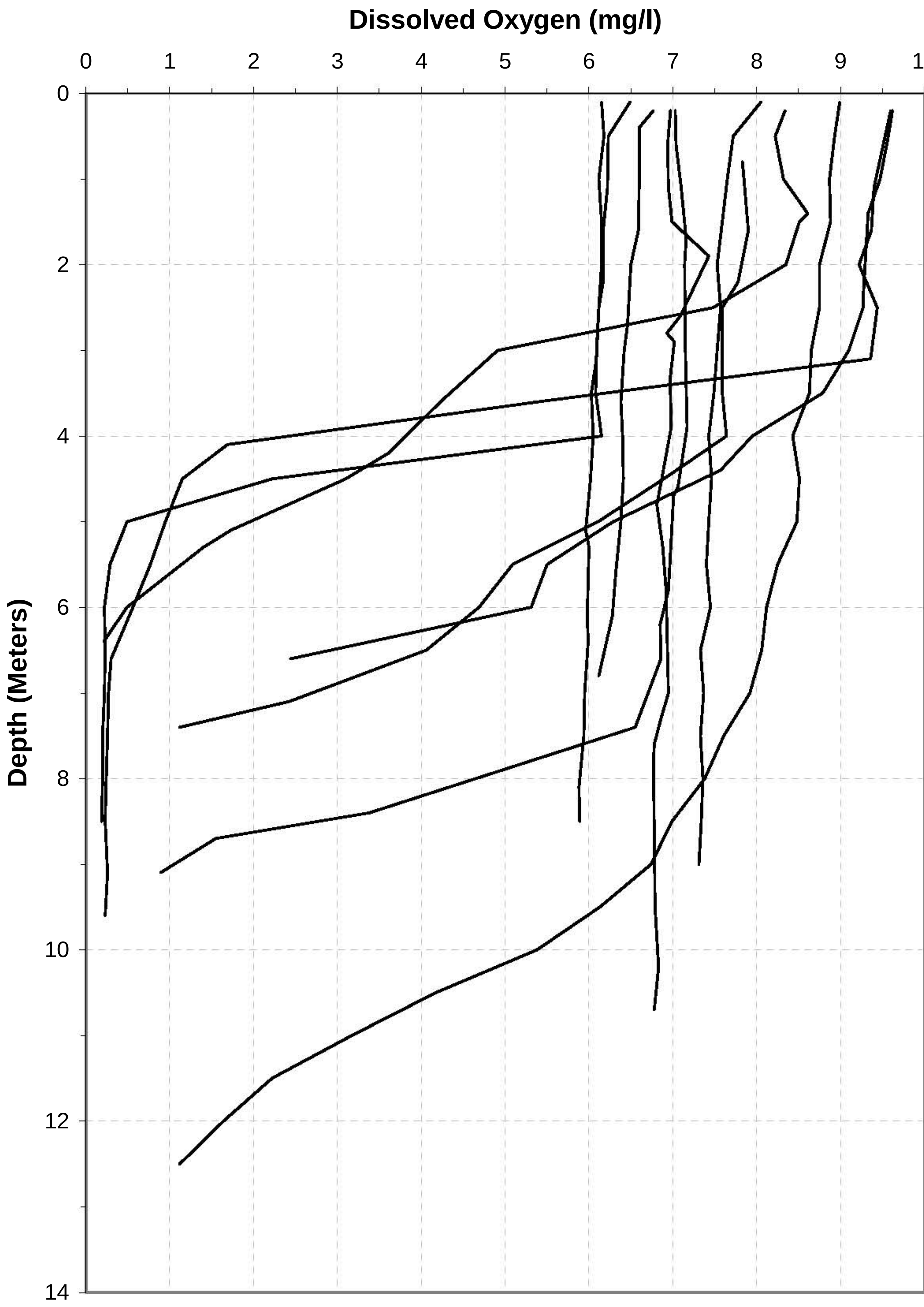

Plate 157. Dissolved oxygen depth profiles for Pipestem Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., PIPLKND1) during the summer over the 3-year period of 2002 through 2004.

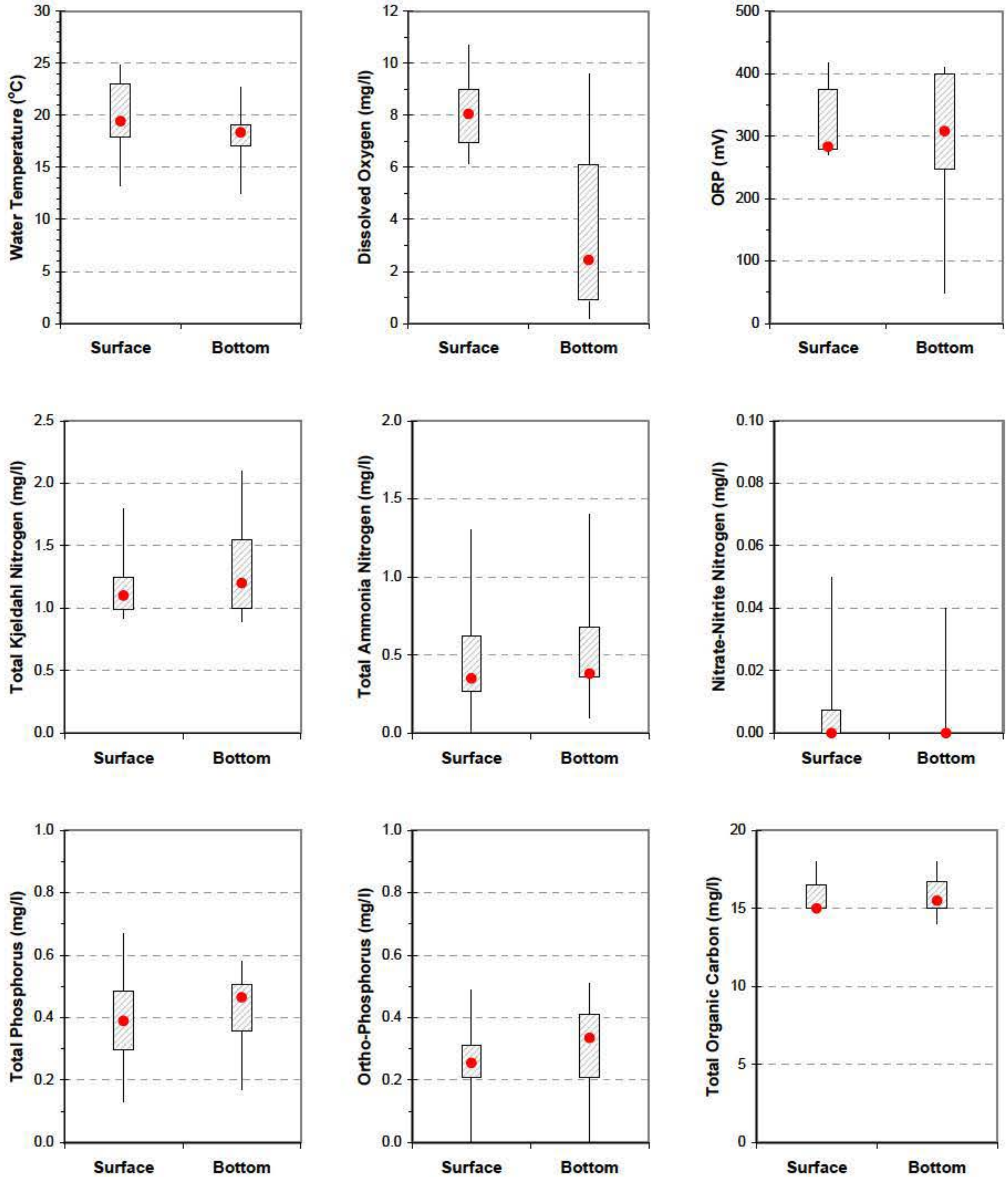

Plate 158. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, ortho-phosphorus, and total organic carbon measured in Pipestem Reservoir at site PIPLKND1 during the summer months of 2002 through 2004. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

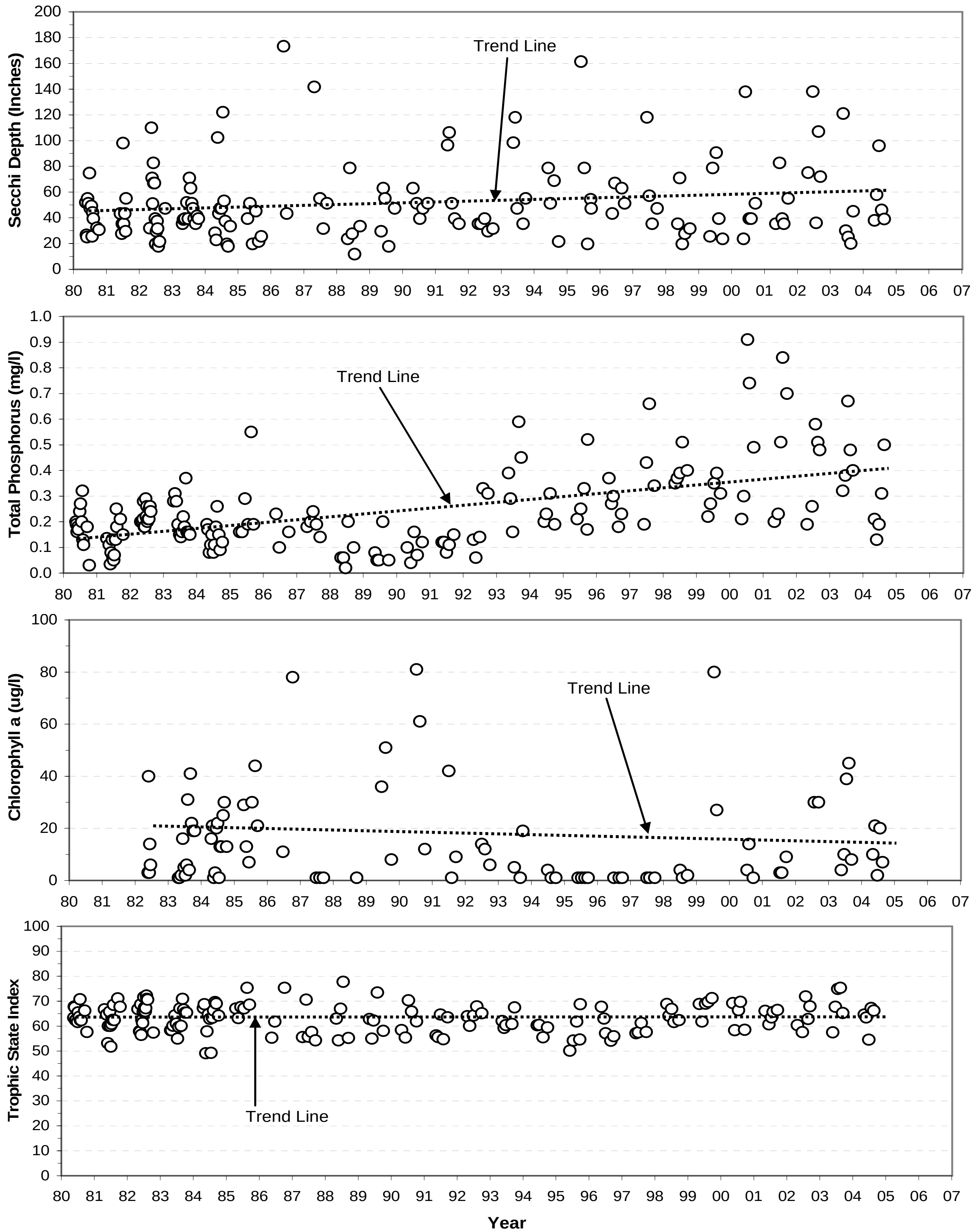

Plate 159. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Pipestem Reservoir at the near-dam, ambient site (i.e., site PIPLKND1) over the 25-year period of 1980 to 2004.

Plate 160. Summary of water quality conditions monitored in Cold Brook Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site CODLKND1) from May to September during 2002 and 2003. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements. Results for chlorophyll a (lab determined), hardness, metals, microcystins, and pesticides are for "grab samples" collected at ½ the measured Secchi depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	8	3582.9	3582.8	3582.4	3583.6	-----	-----	-----
Water Temperature (C)	0.1	166	20.4	21.1	11.3	25.7	18.3[(1)], 23.8[(2)], 26.6[(3)]	120, 40, 0	72%, 24%, 0%
Dissolved Oxygen (mg/l)	0.1	166	8.7	8.7	0.2	12.5	≥ 7, ≥ 6	11, 8	7%, 5%
Dissolved Oxygen (% Sat.)	0.1	166	105.2	107.2	2.2	165.5	-----	-----	-----
Specific Conductance (umho/cm)	1	166	489	478	441	614	-----	-----	-----
pH (S.U.)	0.1	166	8.2	8.2	7.3	8.5	≥6.6 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	41	1.3	0.9	n.d.	4.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	41	348	317	143	441	-----	-----	-----
Secchi Depth (in.)	1	8	219	216	143	303	-----	-----	-----
Alkalinity, Total (mg/l)	7	15	161	158	141	187	-----	-----	-----
Ammonia, Total (mg/l)	0.01	8	0.35	0.31	n.d.	1.00	3.15 [(4,5)], 0.96 [(4,6)]	0, 1	0%, 13%
Chlorophyll *a* (ug/l) – Lab Determined	1	4	2	2	1	4	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	234	233	215	257	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	16	-----	n.d.	n.d.	1.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	16	-----	n.d.	n.d.	0.07	10[(8)]	0	0%
Phosphorus, Total (mg/l)	0.01	16	0.08	0.03	n.d.	0.73	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	16	-----	n.d.	n.d.	n.d.	-----	-----	-----
Suspended Solids, Total (mg/l)	4	16	-----	n.d.	n.d.	9	53[(5)], 30[(6)]	0	0%
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[(7)]	0	0%
Arsenic, Dissolved (ug/l)	3	2	4	4	3	6	340[(5)], 150[(6)], 0.018[(7)]	0, 0, 2	0%, 0%, 100%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4[(7)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	9.3[(5)], 1.9[(6)]	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	1,097[(5)], 356[(6)]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	37.8[(5)], 23.4[(6)], 1,300[(7)]	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	159[(5)], 6.2[(6)]	0	0%
Mercury, Dissolved (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.4[(5)]	0	0%
Mercury, Total (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	0.012[(6)]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	2,895[(5)], 322[(6)]	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14.8[(5)]	0	0%
Zinc, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	234[(5)], 214[(6)],7,400[(7)]	0	0%
Alachlor, Total (ug/l)***	0.05	5	-----	n.d.	n.d.	0.08	-----	-----	-----
Atrazine, Total (ug/l)***	0.05	5	-----	n.d.	n.d.	0.12	-----	-----	-----
Metolachlor, Total (ug/l)***	0.05	5	-----	n.d.	n.d.	0.07	-----	-----	-----
Pesticide Scan (ug/l)****	0.05	1	-----				*****	-----	-----

n.d. = Not detected., b.d. = Below detection limit

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Water temperature criterion for protection of coldwater permanent fish life propagation.
(2) Water temperature criterion for protection of coldwater marginal fish life propagation.
(3) Water temperature criterion for protection of warmwater permanent fish life propagation.
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 21.1 respectively.
(5) Acute criterion for aquatic life.
(6) Chronic criterion for aquatic life.
(7) Human health criterion for surface waters.
(8) Daily maximum criterion for domestic water supply.

Note: North Dakota's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 233 mg/l.

*** Immunoassay analysis.

**** The pesticide scan (GCMS) includes: acetochlor, alachlor, atrazine, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, metolachlor, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 161. Summary of water quality conditions monitored in Cold Brook Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site CODLKML1) from May to September during 2002 and 2003. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, and ORP are for water column profile measurements.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	8	3582.9	3582.8	3582.4	3583.6	-----	-----	-----
Water Temperature (C)	0.1	106	20.6	20.9	14.4	25.8	18.3[(1)], 23.8[(2)], 26.6[(3)]	80, 31, 0	75%, 31%, 0%
Dissolved Oxygen (mg/l)	0.1	106	9.0	8.9	6.6	14.9	≥ 7, ≥ 6	4, 0	4%, 0%
Dissolved Oxygen (% Sat.)	0.1	106	109.4	105.0	72.7	194.1	-----	-----	-----
Specific Conductance (umho/cm)	1	106	480	478	443	530	-----	-----	-----
pH (S.U.)	0.1	106	8.3	8.3	8 1	8.5	≥6.6 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	32	0.9	0.8	n.d.	2.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	32	360	330	313	419	-----	-----	-----
Secchi Depth (in.)	1	7	198	220	130	252	-----	-----	-----

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [(1)] Water temperature criterion for protection of coldwater permanent fish life propagation.
[(2)] Water temperature criterion for protection of coldwater marginal fish life propagation.
[(3)] Water temperature criterion for protection of warmwater permanent fish life propagation.

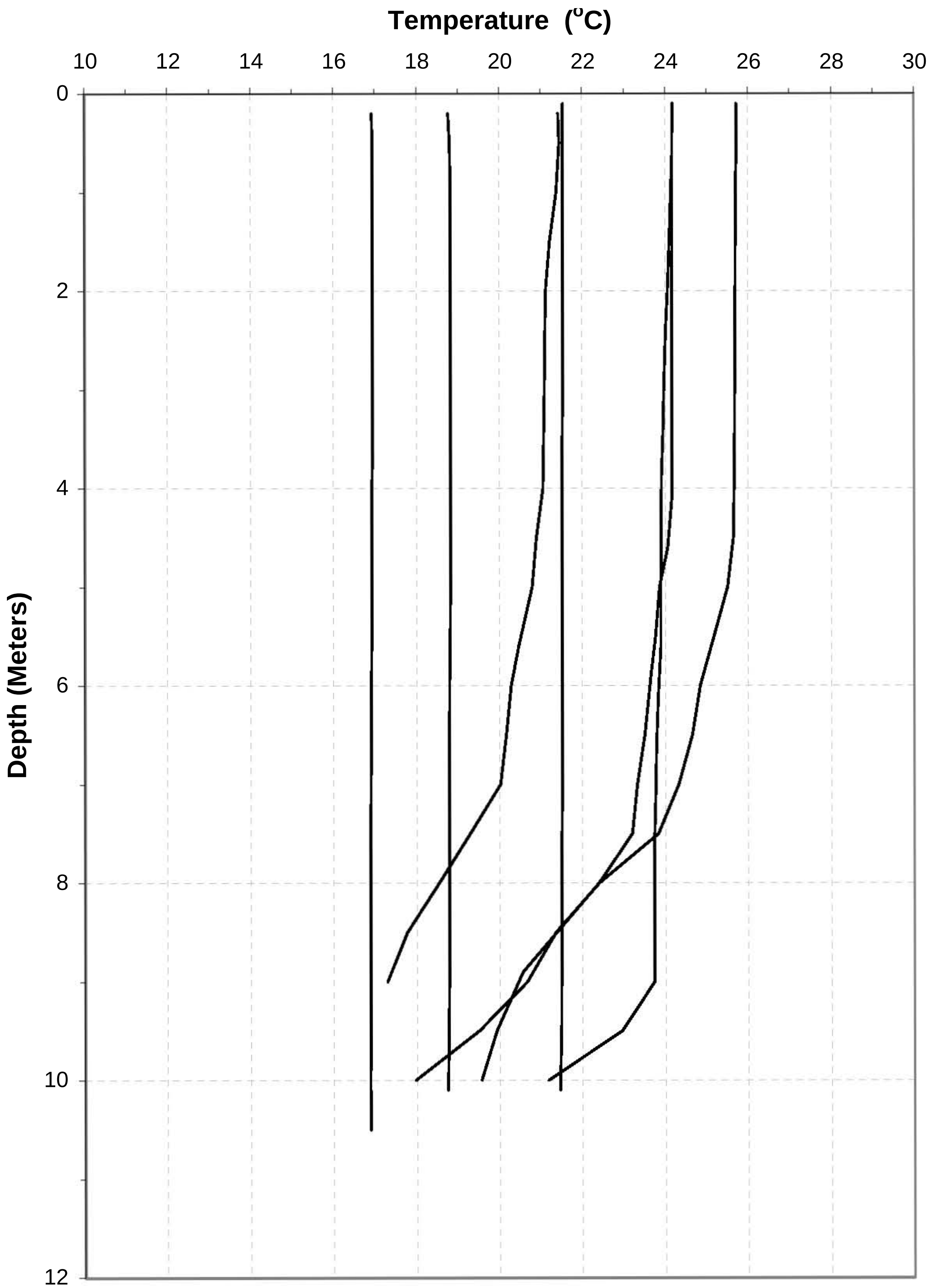

Plate 162. Temperature depth profiles for Cold Brook Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., CODLKND1) during the summer over the 2-year period of 2002 through 2003.

Plate 163. Dissolved oxygen depth profiles for Cold Brook Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., CODLKND1) during the summer over the 2-year period of 2002 through 2003.

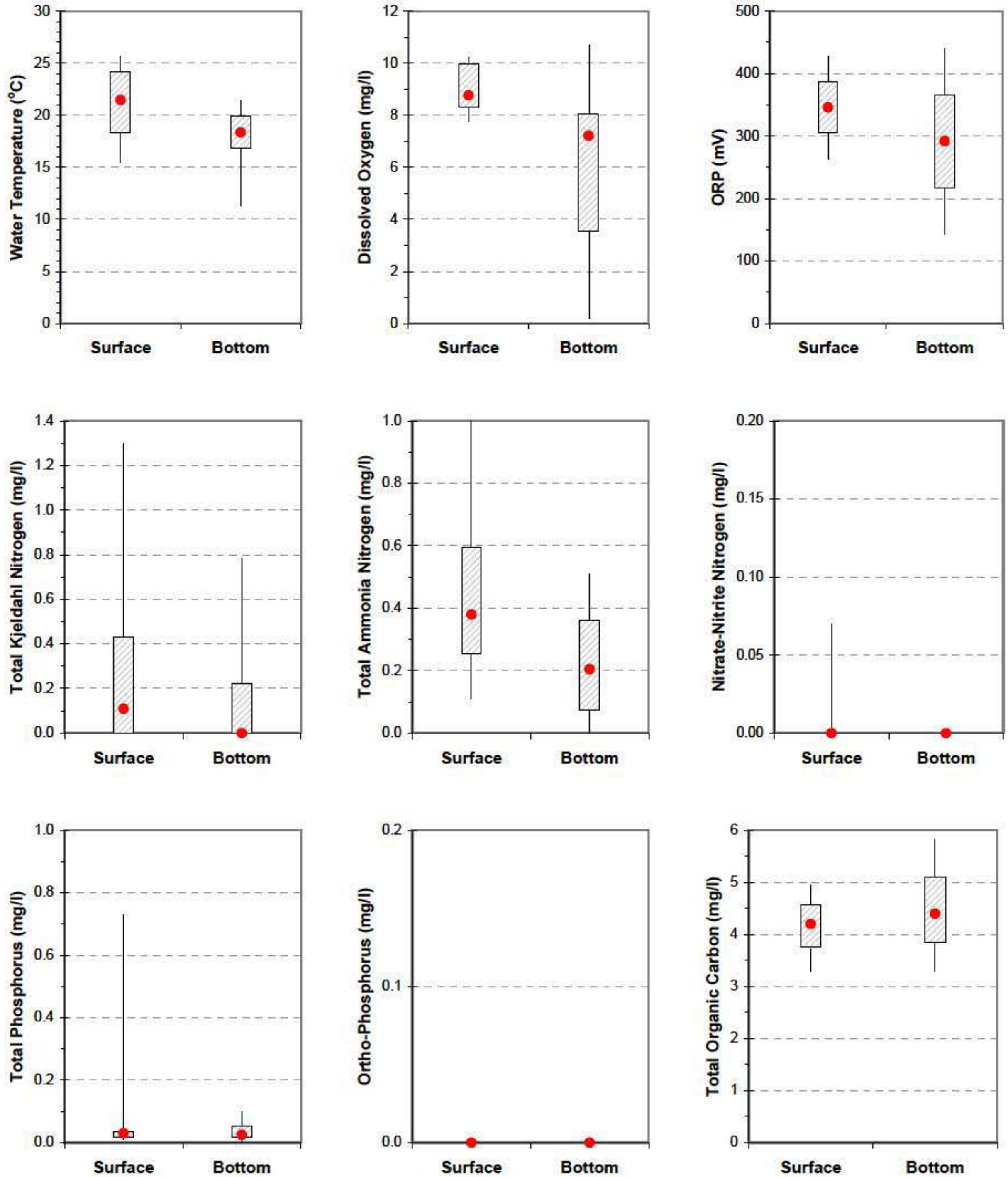

Plate 164. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential (ORP), total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, ortho-phosphorus, and total organic carbon measured in Cold Brook Reservoir at site CODLKND1 during the summer months of 2002 and 2003. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)

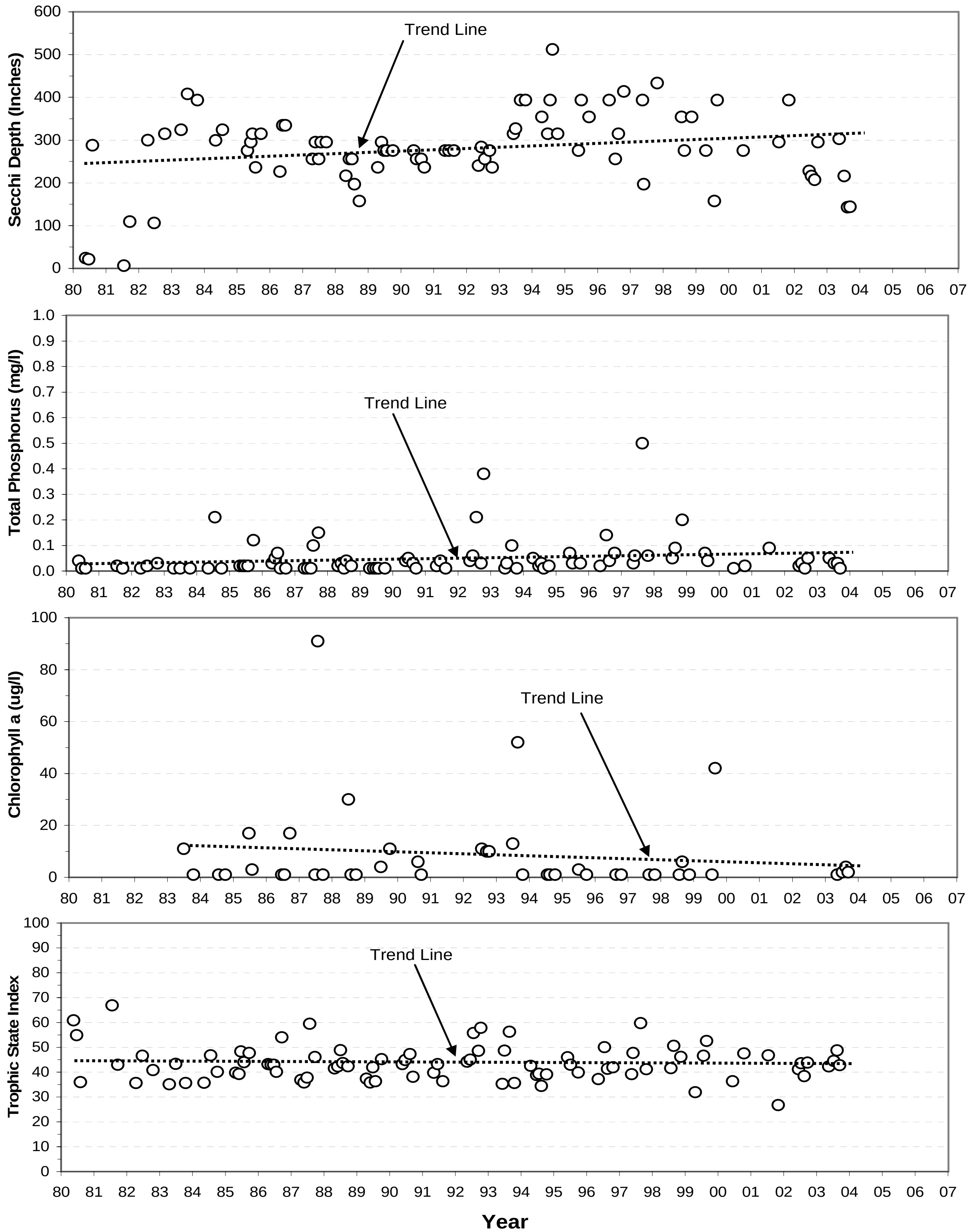

Plate 165. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Cold Brook Reservoir at the near-dam, ambient site (i.e., site CODLKND1) over the 24-year period of 1980 to 2003.

Plate 166. Summary of water quality conditions monitored in Cottonwood Springs Reservoir at the near-dam, deepwater ambient monitoring location (i.e., site COTLKND1) from May to September during 2002. [Note: Results for water temperature, dissolved oxygen, conductivity, and pH are for water column profile measurements. Results for hardness, metals, and pesticides are for “grab samples” collected at ½ the measured Secchi depth. Results for other parameters are for “grab samples” collected at near-surface and near-bottom depths.]

	Monitoring Results						Water Quality Standards Attainment		
Parameter	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	3864.6	3864.6	3863.8	3865.6	-----	-----	-----
Water Temperature (C)	0.1	71	19.6	20.6	13 9	25.6	26.6	0	0%
Dissolved Oxygen (mg/l)	0.1	71	7.0	7.3	0 3	8.7	≥ 6, ≥ 5	10, 6	14%, 8%
Dissolved Oxygen (% Sat.)	0.1	71	88.8	89.3	2 9	118.6	-----	-----	-----
Specific Conductance (umho/cm)	1	71	1,770	1,751	1,702	1,829	-----	-----	-----
pH (S.U.)	0.1	71	8.0	8.0	7.4	8.2	≥6.6 & ≤9.0	0	0%
Secchi Depth (in.)	1	4	215	225	146	264	-----	-----	-----
Alkalinity, Total (mg/l)	7	8	80	82	51	104	-----	-----	-----
Hardness, Total (mg/l)	0.4	6	1,139	1,149	1,037	1,233	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	8	-----	n.d.	n.d.	0.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	8	-----	n.d.	n.d.	n.d.	10[4]	0	0%
Phosphorus, Total (mg/l)	0.01	8	0.03	0.03	0.02	0.05	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	8	-----	n.d.	n.d.	n.d.	-----	-----	-----
Suspended Solids, Total (mg/l)	4	8	-----	n.d.	n.d.	6	53[1], 30[2]	0	0%
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	340[1], 150[2], 0.018[3]	0, 0, 2	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	9.3[1], 1.9[2]	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	1,097[1], 356[2]	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	37.8[1], 23.4[2], 1,300[3]	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	159[1], 6.2[2]	0	0%
Mercury, Dissolved (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	2,895[1], 322[2]	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	14.8[1]	0	0%
Zinc, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	234[1], 214[2],7,400[3]	0	0%
Alachlor, Total (ug/l)***	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)***	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Metolachlor, Total (ug/l)***	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected., b.d. = Below detection limit

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Acute criterion for aquatic life.
(2) Chronic criterion for aquatic life.
(3) Human health criterion for surface waters.
(4) Daily maximum criterion for domestic water supply.
Note: North Dakota’s WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 1,149 mg/l.

*** Immunoassay analysis.

Plate 167. Summary of water quality conditions monitored in Cottonwood Springs Reservoir at the mid-lake, deepwater ambient monitoring location (i.e., site COTLKML1) from May to September during 2002 and 2003. [Note: Results for water temperature, dissolved oxygen, conductivity, and pH are for water column profile measurements.]

	Monitoring Results						Water Quality Standards Attainment		
Parameter	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	3864.6	3864.6	3863.8	3865.6	-----	-----	-----
Water Temperature (C)	0.1	62	20.3	21.0	14.6	25.6	26.6	0	0%
Dissolved Oxygen (mg/l)	0.1	62	7.1	7.3	2.4	8.9	≥ 7, ≥ 6	6, 6	10%, 10%
Dissolved Oxygen (% Sat.)	0.1	62	91.6	90.6	32.8	117.9	-----	-----	-----
Specific Conductance (umho/cm)	1	62	1,771	1,761	1,706	1,827	-----	-----	-----
pH (S.U.)	0.1	62	8.0	8.0	7.4	8.2	≥6.6 & ≤9.0	0	0%
Secchi Depth (in.)	1	4	223	219	202	252	-----	-----	-----

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** (1) Water temperature criterion for protection of coldwater permanent fish life propagation.
(2) Water temperature criterion for protection of coldwater marginal fish life propagation.
(3) Water temperature criterion for protection of warmwater permanent fish life propagation.

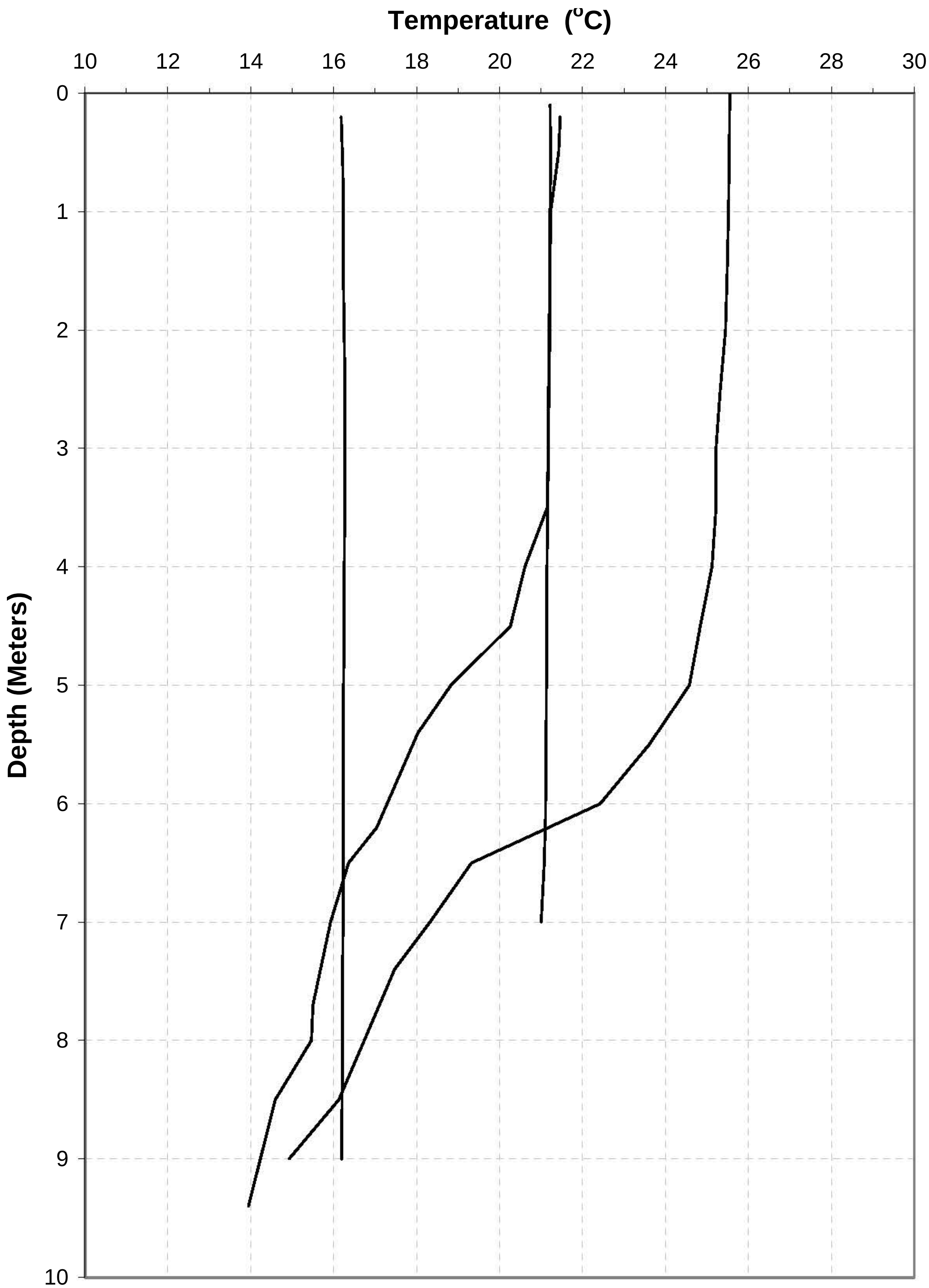

Plate 168. Temperature depth profiles for Cottonwood Springs Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., COTLKND1) during the summer of 2002.

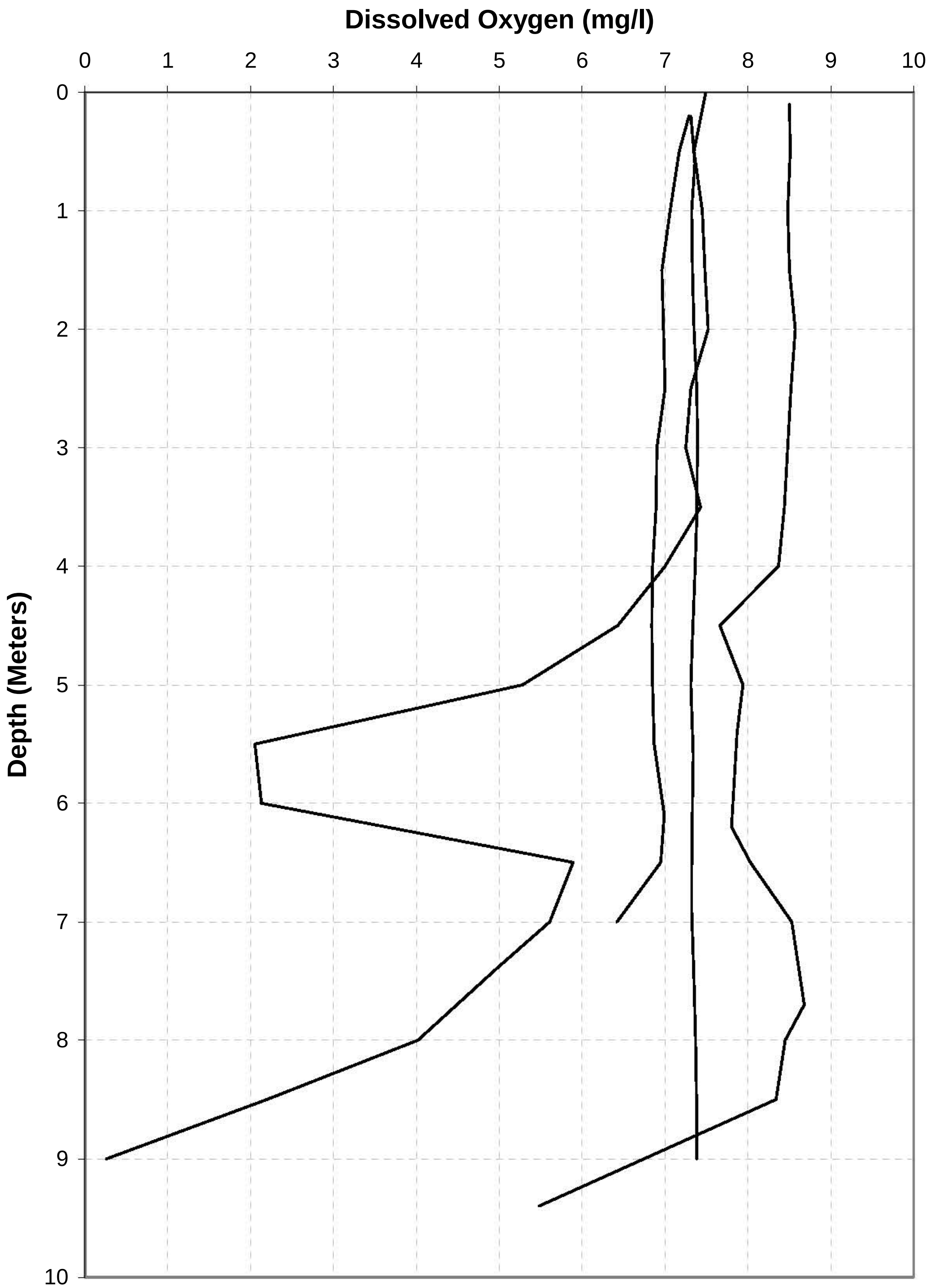

Plate 169. Dissolved oxygen depth profiles for Cottonwood Springs Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., COTLKND1) during the summer of 2002.

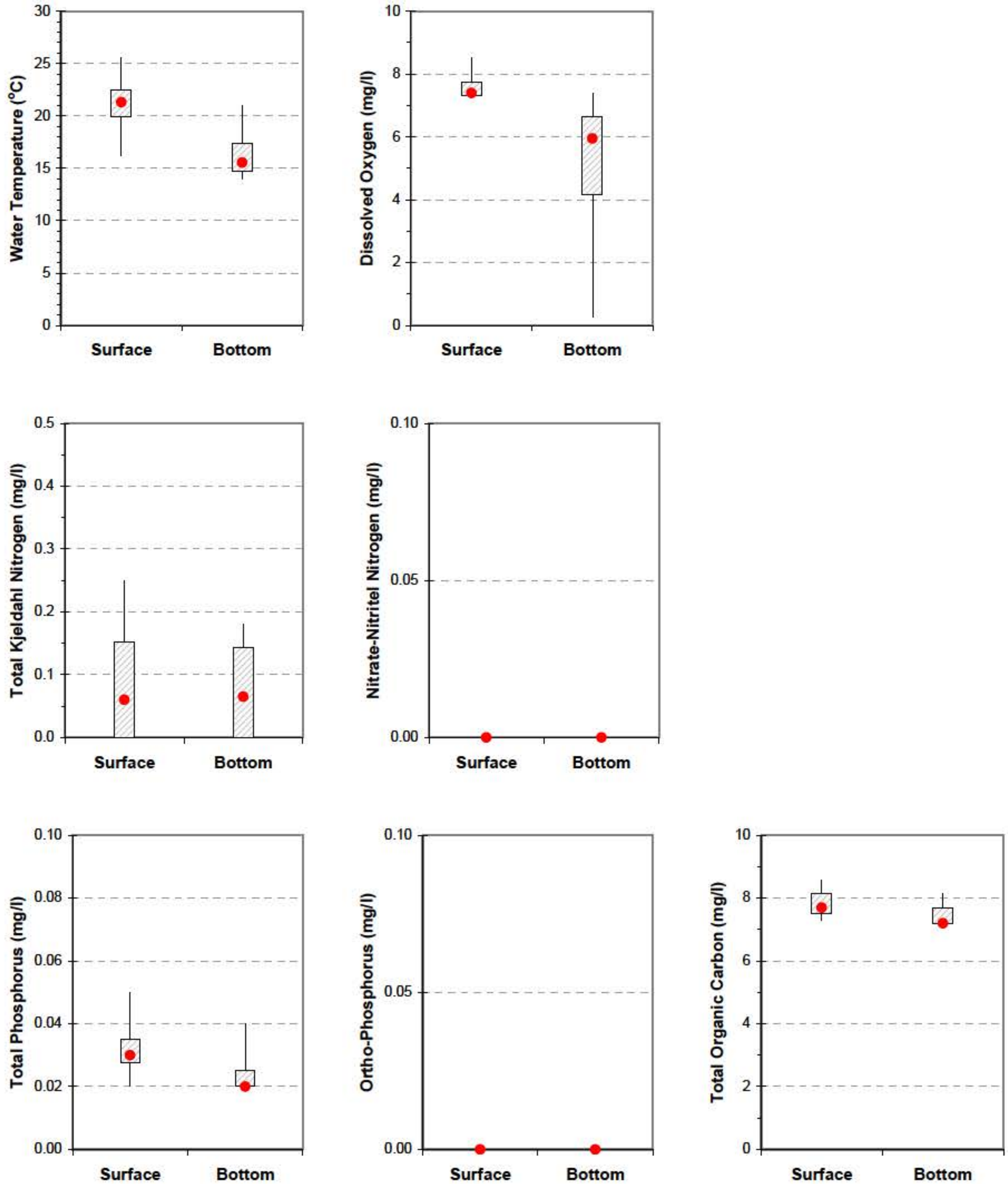

Plate 170. Box plots comparing surface and bottom water temperature, dissolved oxygen, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, total phosphorus, ortho-phosphorus, and total organic carbon measured in Cottonwood Springs Reservoir at site COTLKND1 during the summer month of 2002. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot. Non-overlapping interquartile ranges of the adjacent box plots indicate a significant difference between surface and bottom measurements.)